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DEVELOPMENT OF LOW FODMAP GLUTEN FREE SOURDOUGH BREAD

A thesis presented in partial fulfillment of requirements for the degree of
Master of Food Technology

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May 2021

Dedication

This work is dedicated to my parents: my mother June Liu and my father Shaolei Tian, who both taught me everything I need to know in my life, who always love and support me with their endless encouragement and kindness.

ABSTRACT

Fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAPs) comprise a group of indigestible short-chain carbohydrates that have gained attention due to their potential to trigger gastrointestinal (GI) symptoms such as abdominal pain, bloating and diarrhea in patients with GI-related disorders (e.g., Crohn's disease, Coeliac disease and Irritable Bowel Syndrome). Certain GI-related disorders are triggered by consuming gluten-containing products, including bread. Gluten-related GI disorders can be prevented by strict adherence to a lifelong gluten-free (GF) diet. Although GF breads are generally low in FODMAPs (total FODMAPs < 0.5 g), consuming quantities that exceed the threshold (0.5 g/meal) may cause symptoms.

Sourdough fermentation has been applied in GF bread for improving its overall quality. Sourdough culture is a complex microbial ecosystem dominated by lactic acid bacteria (LAB) and yeast which can degrade FODMAP sugars during fermentation. This study quantified FODMAPs in seven commercial GF breads (three conventional GF breads and four GF sourdough breads) in New Zealand by HPAEC-PAD and enzymatic assay. This study also reformulated existing formulation and applied retard proofing (fermentation at refrigeration temperature) to reduce the FODMAPs in the GF sourdough bread.

Results showed that the GF sweet potato sourdough bread (GFSD1) formulation (Control) contained the highest FODMAP levels. Three strategies were applied to reformulate the existing formulation and investigate the effects on the reduction of FODMAPs in GF sweet potato sourdough bread as follows: replacing coconut sugar with rice syrup (low FODMAP ingredient) (RS); reducing kumara flour (potentially high in mannitol) from 2.81 % to 1.50 % (RS/RK); increasing the percentage of sourdough starter from 24.31 % to 35.00 % (RS/ISD). Retard proofing (12 h at 8 °C/87 % RH) was applied to the Control formulation (Control/RP) instead of existing proofing conditions (1 h at 37 °C/87 % RH) to investigate the effect of different fermentation processes on reduction of FODMAPs in GF sourdough bread. The microbiological and physical-chemical characteristics and FODMAP content of GF sourdough starter during propagation were determined. The bread dough samples before and after proofing were collected for measurement of microbiological and physical-chemical characteristics as well as FODMAP analysis. The baking characteristics, sensory properties and FODMAP content of GF sweet potato sourdough bread samples were also analysed.

The pH of the GF sourdough starter decreased during propagation of the sourdough starter, while the LAB and yeast cell density, total titratable acid (TTA), lactic and acetic acids increased ($p < 0.05$). GF sourdough starter contained very low amounts of FODMAPs, and the overall FODMAP content decreased during propagation for 72 h. Significant growth of the LAB and yeast cell density were observed in all the bread dough samples during proofing ($p < 0.05$). After proofing, the pH of all the bread doughs decreased ($p < 0.05$), while the TTA increased due to increasing concentrations of lactic and acetic acids. Addition of a high percentage of sourdough starter enhanced sourdough acidification reflected by the lowest pH, and the highest TTA and concentrations of organic acids of the RS/ISD bread dough samples. The concentrations of lactic and acetic acids of bread doughs made with rice syrup (RS, RS/RK) were lower than that made with coconut sugar (Control and Control/RP) ($p < 0.05$), indicating the impact of the type of sugar on the carbohydrate metabolism of LAB and sourdough acidification. The fermentation quotient of the Control/RP (2.74) was close to the optimum FQ range (2.00 - 2.70) recommended for producing superior sourdough bread.

Fructose, glucose and total fructans were reduced in all the bread dough samples during proofing. Only trace amounts of sugar polyols (sorbitol and mannitol), galacto-oligosaccharides (raffinose and stachyose) and fructo-oligosaccharides (nystose) were detected in the bread dough and bread samples. Replacing coconut sugar with rice syrup in the bread formulation significantly reduced the amounts of excess fructose, mannitol and total fructans in both bread dough and bread samples ($p < 0.05$). Control/RP bread produced by retard proofing contained lower total fructans than the Control bread ($p < 0.05$). However, the RS/RK and RS/ISD formulations had negligible effects on further reducing FODMAPs in GF sweet potato sourdough bread.

Although GF sweet potato sourdough breads made with rice syrup (RS, RS/RK and RS/ISD) contained lower levels of FODMAPs, the overall baking characteristics and consumer acceptability were lower than the Control and the Control/RP breads made with coconut sugar. Reducing kumara flour and increasing the percentage of sourdough starter negatively impacted on the crumb loaf and crumb texture, resulting in lower sensory scores for the aroma, taste and overall acceptability. However, retard proofing not only reduced the total FODMAPs in GF sweet potato sourdough breads, but it also increased loaf volume, reduced baking weight loss, enhanced crumb softness, cohesiveness and resilience ($p < 0.05$). The Control/RP bread received the highest sensory scores for all the attributes ($p < 0.05$), and it was well-accepted by sensory panelists. Therefore, retard proofing could be considered as a low-cost application in the development of low FODMAP GF sourdough breads.

ACKNOWLEDGEMENTS

I would first like to thank Venerdi (NZ) Ltd. for providing funding, supplies, and technical support for this study. I greatly appreciate this precious opportunity of exploring the science and food technology of the gluten-free and bakery industry.

I would like to thank my main supervisor, Dr. Tony Mutukumira, for his contribution and advice, continuous support and guidance throughout my Masters study and life. I would say working with him was really enjoyable, because his enthusiasm and encouragement always motivated me. Thanks go to my co-supervisor, Associate Prof. Kay Rutherford-Markwick, for her patience, constant support and guidance throughout this research. I also want to extend my gratitude to Prof. Marie Wong, for her invaluable knowledge and advice on sugars and organic acids analysis, and HPLC training.

I would like to thank all the School of Food and Advanced Technology staff, who gave me advice and assistance during the time I conducted my experiments. John Sykes at Palmerston North campus, for his expertise in HPLC instruments and advice on HPLC column selection. Dr Nuri Begum and Negah Nikanjam, for their training in the chemistry and food product development laboratory, technical support and general assistance for analytical instruments. Rachel Liu, for her training as well as guidance in the microbiology laboratory.

I would like to acknowledge Dr. Chuanfeng Huang and Dr. Haiyan Wang from the National Institutes for Food and Drug Control (Beijing, China), for providing HPAEC-PAD instruments for this study, and technical support and guidance for FODMAP analysis.

Finally, I would like to thank my parents, for their endless love, support and encouragement. My husband, Bo Cao, for his support and encouragement throughout the days I studied for my research project and lived in NZ. Without the inspiration of my family, I could not have completed this study.

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LIST OF ABBREVIATIONS

AACC	American Association of Cereal Chemists
Ac ⁻	acetate ion
acetyl-CoA	acetyl coenzyme A
acetyl-P	acetyl phosphate
AcOH	glacial acetic acid
AEX	anion-exchange
ANOVA	analysis of variance
APC	total aerobic plate counts
ATIs	amylase-trypsin-inhibitors
ATP	adenosine triphosphate
Aw	water activity
CD	coeliac disease
CFU/g	colony-forming units per gram
CH ₃ CN	acetonitrile
CIE	International Commission on Illumination
CO ₂	carbon dioxide
DHAP	dihydroxyacetone phosphate
DP	degrees of polymerisation
DY	dough yield
EMP	Embden-Mayerhoff Parnas
EPS	exopolysaccharides
FODMAPs	fermentable oligo-, di-, and monosaccharides, and polyols
FOS	fructo-oligosaccharides
FQ	fermentation quotient
G-6-P	glucose 6-phosphate
G-6-PDH	glucose 6-phosphate dehydrogenase
GABA	γ-aminobutyric acid
GAP	glyceraldehyde-3-phosphate
GC-MS	gas chromatography coupled with mass spectrometry
GF	gluten-free
GI	gastrointestinal
GOS	galacto-oligosaccharides
HePS	heteropolysaccharides
HK	hexokinase
HMW-GS	high-molecular-weight glutenin subunits
HoPS	homopolysaccharides
HPAEC-PAD	high-performance anion-exchange chromatography with pulse amperometric detector
HPLC	high-performance liquid chromatography
HPLC-ELSD	high-performance liquid chromatography equipped with evaporative light scattering detection

HPLC-RI	high-performance liquid chromatography equipped with refractive index detection
IBD	inflammatory bowel disease
IBS	irritable bowel syndrome
IBS-D	diarrhea predominant IBS
KHP	potassium hydrogen phthalate
LAB	lactic acid bacteria
LDH	lactate dehydrogenase
LMW-GS	low-molecular-weight glutenin subunits
MeOH	methanol
MRS	De Man, Rogosa and Sharpe agar
MW	molecular weights
N ₂	nitrogen
NAD ⁺	nicotinamide adenine dinucleotide
NADH	nicotinamide adenine dinucleotide + hydrogen
NADPH	nicotinamide adenine dinucleotide phosphate + hydrogen
NaOAc	sodium acetate
NaOH	sodium hydroxide
NCGS	non-coeliac gluten sensitivity
NCWS	non-coeliac wheat sensitivity
NZ	New Zealand
OH ⁻	hydroxide ions
PAD	pulsed amperometric detection
PCA	Plate Count Agar
PGI	phosphoglucose isomerase
RH	relative humidity
RSD	relative standard deviation
SCFAs	short-chain fatty acids
SD	standard deviation
sp.	species
spp.	several species, indicate many species of the same genus
TCA	tricarboxylic acid
TPA	texture profile analysis
TTA	total titratable acid
w/v	weight by volume
w/w	weight by weight
YGC	Yeast Extract Glucose Chloramphenicol Agar

CHAPTER 1 INTRODUCTION

In recent years, an increasing number of people have been diagnosed with gastrointestinal (GI) related diseases associated with the ingestion of foods containing gluten, including bread (Muir et al., 2019). Coeliac disease (CD) and non-coeliac gluten or wheat sensitivity (NCGS/NCWS) are frequently diagnosed GI immune-mediated systemic disorders triggered by gluten ingestion, which affect about 1 % and 6 % of the global population, respectively (Dickey & Kearney, 2006; Picarelli et al., 2013). Irritable bowel syndrome (IBS) is another group of functional bowel disorder induced by altered bowel habits. IBS constitutes the majority of health problems associated with GI symptoms, affecting approximately 11 % of the general population (Lovell & Ford, 2012). Crohn's disease is an inflammatory bowel disease (IBD) that can affect any part of GI tract and may cause symptoms similar to IBS such as diarrhea, abdominal pain and cramping (Gibson & Shepherd, 2005).

Gluten is the major storage protein found in cereal grains (e.g., wheat, barley, rye) (Arendt et al., 2008), but it contains toxic gliadin peptides fraction that trigger the T cell-mediated immune response of patients with CD (Sollid & Khosla, 2005), and the innate immune response of patients with NCGS (Sapone et al., 2009). Fermentable oligosaccharides, disaccharides, monosaccharides and polyols (FODMAPs) which are naturally present in daily food sources, are also dietary triggers of GI symptoms for patients with GI-related disorders (Muir et al., 2019). As FODMAPs are indigestible and unabsorbed, they can reach the colon and cause water to be dragged into the gut lumen due to osmotic stress (Gibson et al., 2007). The carbohydrates are rapidly fermented by the gut bacteria and produce substantial amounts of gas resulting in luminal distension, which is the major cause of many IBS symptoms (Barrett et al., 2010; Halmos et al., 2014).

The only available treatment for people suffering from CD and NCGS or NCWS is strict adherence to a lifelong gluten-free (GF) diet (Bascuñán et al., 2017). A low FODMAP-diet has been effectively used to reduce the GI symptoms of IBS and Crohn's disease patients (Gearry et al., 2009; Gibson & Shepherd, 2009; Staudacher et al., 2011). Recent studies started to combine a GF-diet with a low FODMAP-diet to help patients with gluten-related GI disorders gain better control of their symptoms and avoid complications associated with these disorders (Roncoroni et al., 2018; Roncoroni et al., 2019). Thus, there is an opportunity to develop well-tolerated low FODMAP GF products suitable for affected patients, which can be used as part of a holistic dietary therapy for management of these GI-related diseases.

Bread is one of the most frequently consumed food products, but it is also the major dietary source of disease-activating components, such as gluten and FODMAPs (Laatikainen et al., 2016). Rising consumer demands for GF breads is correlated with the increase of people diagnosed with GI-related disorders. However, GF breads usually have low crumb volume and have a rapid staling rate due to the absence of gluten (Gallagher, Gormley & Arendt, 2003; Naqash et al., 2017). Gluten is the major factor contributing to the structural properties of baked products and provides viscoelastic properties to the dough and unique features for baking performance (Arendt et al., 2008). For this reason, numerous studies have focused on the development of GF formulations to improve the overall quality and nutritional characteristics of GF breads (Gallagher et al., 2004; Moroni, Dal Bello & Arendt, 2009; Arendt & Moroni, 2013; O Shea et al., 2014; Nionelli & Rizzello, 2016).

Sourdough fermentation is the oldest leavening technology dating back to ancient Egypt (Chavan & Chavan, 2011). It is still widely applied in modern baking industries due to its effectiveness in improving the quality of bread products, and unique sourdough aroma and flavour (Gobbetti, 1998; Arendt et al., 2007; Corsetti & Settanni, 2007). In recent decades, particular interest has been given to using sourdough to produce palatable GF breads, as sourdough fermentation can improve textural properties, generate aromatic and flavour

compounds, retard bread staling, extend shelf life and enhance the nutritional values of GF breads (Moroni, Dal Bello & Arendt, 2009; Vogelmann et al., 2009; Nionelli & Rizzello, 2016).

The FODMAP content of bread depend on the types of ingredients and grains used within the bread formulation (Biesiekierski et al., 2011). Development of low FODMAP bread can be achieved by using low FODMAP ingredients (such as GF flours and ingredients) (Ispiryan, Zannini & Arendt, 2020), and through longer yeast fermentation to degrade fructans into glucose and fructose by the enzyme invertase (Lammens et al., 2009). Additionally, sourdough fermentation represents a novel technology for making low FODMAP bread as it contains specific strains of *Lactobacillus*, utilises a prolonged fermentation time and creates a favorable acidic environment for enzymatic activities of yeasts and lactic acid bacteria (LAB), which can promote the degradation of FODMAPs within the breads (Teixeira et al., 2012; Knez, Abbott & Stangoulis, 2014; Gänzle, 2015; Ziegler et al., 2016; Struyf et al., 2017; Loponen & Gänzle, 2018).

To the authors knowledge, no previous study has investigated the effects of sourdough fermentation on FODMAPs in GF breads and the quality characteristics of low FODMAP GF sourdough bread. Therefore, this research was aimed to quantify FODMAPs in seven commercial GF breads (three conventional GF breads and four GF sourdough breads) produced by a local company in New Zealand, and to reduce the levels of FODMAPs in existing GF sourdough bread containing the highest levels of FODMAPs by reformulating and using retard proofing (fermentation at refrigeration temperature). The effects of sourdough fermentation on the FODMAP degradation and the characteristics of low FODMAP GF sourdough breads were studied with the following objectives.

Objectives:

1. To quantify FODMAPs (including total fructans) in seven commercial GF breads (three conventional GF breads and four GF sourdough breads) produced by a local company in New Zealand using high-performance anion-exchange chromatography with pulse amperometric detector (HPAEC-PAD) and enzymatic assay;
2. To reduce the levels of FODMAPs in existing GF sweet potato sourdough bread through reformulation and using retard proofing (fermentation at refrigeration temperature);
3. To investigate the effects of sourdough fermentation on the microbiological and physico-chemical characteristics, and the FODMAPs of GF sourdough starter during propagation;
4. To investigate the effects of different formulations and fermentation processes on the microbiological and physico-chemical characteristics, and the FODMAPs of bread dough samples (before and after proofing) and bread samples of GF sweet potato sourdough breads; And,
5. To investigate the effects of different formulations and fermentation processes on the baking characteristics and sensory properties of GF sweet potato sourdough breads.

CHAPTER 2 LITERATURE REVIEW

2.1 FODMAPs

FODMAPs is an acronym that stands for fermentable oligosaccharides, disaccharides, monosaccharides, and polyols (Gibson et al., 2007). It is used to describe a group of fermentable and indigestible short-chain carbohydrates that are naturally present in foods in variable quantities, including excess fructose (apple, pear, corn syrup, etc.), lactose (milk, yoghurt, cheese, etc.), fructans and fructo-oligosaccharides (FOS) (wheat, rye, cereal, etc.), galacto-oligosaccharides (GOS) (beans, lentils, chickpeas, etc.), and sugar polyols (apple, peach, artificial sweeteners, etc.) (Muir et al., 2009). In the last decade, this group of carbohydrates has gained more attention due to its potential risks in triggering GI symptoms in patients with Crohn's disease and IBS (Gibson & Shepherd, 2005; Gibson & Shepherd, 2009).

There is evidence linking FODMAPs and development of GI symptoms (Halmos et al., 2014; Shepherd et al., 2013; Muir et al, 2019). Typical GI symptoms such as luminal distention and abdominal pain are due to increased fluid in the lumen due to osmotic effects and visceral hypersensitivity which occurs when poorly absorbed FODMAPs pass through the small intestine (Barrett et al., 2010). Bacterial fermentation of FODMAPs in the colon produces hydrogen and methane gasses, which contribute to flatulence and bloating symptoms (Dugum, Barco & Garg, 2016). Increased fluid delivery to the bowel due to the osmotic effects of FODMAPs may result in a laxative effect and induce diarrhea (Gibson & Shepherd, 2009). Malabsorption of higher levels of FODMAPs can cause greater amounts of water to be delivered to the lumen and production of more gasses by bacterial fermentation. The level of malabsorption is dependent on the amounts of the FODMAPs ingested and the polymerisation of the saccharides (Gibson & Shepherd, 2012).

2.2 Types of FODMAPs

Fructose is a hexose sugar that can be ingested into small intestine in three different forms, free monosaccharide, disaccharide (sucrose) and polymerised forms (fructans, fructo-oligosaccharides and inulins) (Hayes, Fraher & Quigley, 2014). It is estimated that around 50 % of the general population affected by fructose malabsorption is unable to absorb 25 g of fructose (Gibson et al., 2007). Absorption of fructose is more rapid when equal or higher levels of glucose are present through co-transportation via the GLUT-2 glucose transporter (Rumessen & Gudmand-Høyer, 1988). However, if fructose is in excess of glucose, fructose malabsorption will occur due to the low capacity of absorption through the GLUT-5 fructose transporter (Putkonen, Yao & Gibson, 2013). Fructose malabsorption can cause intestinal distention and visceral hypersensitivity that can further induce and exacerbate GI symptoms (Barrett & Gibson, 2007; Shepherd et al., 2008).

Lactose is a disaccharide found in milk and other dairy products, consisting of glucose and galactose, which can potentially trigger GI symptoms such as diarrhea which is predominant in IBS (IBS-D) (Böhmer & Tuynman, 2001). The absorption of lactose occurs through enzymatic hydrolysis by lactase. Partial hydrolysis of lactose due to lack of the enzyme lactase in susceptible individuals can cause lactose malabsorption (Vernia et al., 1995). Gas production through bacterial fermentation of unabsorbed lactose in the colon can cause abdominal pain, bloating and diarrhea (Hayes, Fraher & Quigley, 2014).

Fructans are oligo- and polysaccharides consisting of fructose molecules joined by β -(2->1) linkages with a D-glucosyl residue at the end. They are mainly found in grains and cereals such as wheat, rye and barley. Fructo-oligosaccharides (FOS) are short-chain fructans made up of 2-9 fructose molecules, and inulins are longer-chain fructans normally containing more than ten fructose molecules (Shepherd & Gibson, 2006). Two major FOS commonly found in food products are kestose and nystose. Kestose is a trisaccharide, composed of two fructose

molecules and one glucose molecule. Nystose is a tetrasaccharide consisting of two fructose molecules linked by β -(2->1) bonds to the fructosyl moiety of sucrose (BeMiller, 2007).

Galacto-oligosaccharides (GOS) usually contain 2-5 galactose molecules and one linked glucose molecule, and are primarily found in legumes, beans and some nuts. Raffinose and stachyose are the most common GOS from dietary sources. Raffinose is made up of one fructose, one glucose and one galactose unit linked together. Stachyose comprises raffinose with an additional galactose unit (Gibson & Shepherd, 2005). The human body does not have digestive enzymes to digest FOS or GOS, so they are not digested in the small intestine and reach the colon. They are fermented by colonic bacteria into gases and short-chain fatty acids (SCFAs), which may induce GI symptoms such as severe pain, diarrhea, and constipation in IBS patients (Hayes, Fraher & Quigley, 2014).

Polyols including sorbitol, mannitol, maltitol and xylitol are poorly absorbed sugar-alcohols, due to their lack of specific transporter mechanisms. These sugar-alcohols are absorbed very slowly and incompletely through passive diffusion, as they are too large to pass through the pores in the small intestinal epithelial cell wall (Barrett & Gibson, 2007; Wilson & Hill, 2014). Unabsorbed polyols can lead to laxative effects in the colon and may cause bloating, flatulence and diarrhea (Khan et al., 2015).

2.3 Dietary Strategies for the Management of GI-related Diseases

2.3.1 Gluten-free diet

Strict lifelong adherence to a gluten-free (GF) diet is the only available therapy for patients with GI-related diseases such as CD and NCGS (Vici et al., 2016). All foods made from grains containing gluten such as wheat, rye and barley must be eliminated from the diet (Catassi et al.,

2007). Even ingestion of trace amounts of contaminating gluten can induce severe damage to the lining of the small intestine of CD patients (Catassi & Fasano, 2008).

Strict omission of gluten from diet results in healing of the small bowel mucosa and remission of the inflammatory GI symptoms (Lanzini et al., 2009). Improved symptomatic and intestinal function as well as intestinal permeability have been observed for patients after being introduced to a GF-diet for two months (Cummins et al., 2001). However, the complete restoration of the small bowel mucosal needs at least a year or more after treatment with a GF-diet (Tuire et al., 2012). GF-diets can also be used as a treatment for subjects who suffer from IBS and NCGS symptoms (Aziz et al., 2016; Niland & Cash, 2018; Volta Volta et al., 2019).

2.3.2 Low FODMAP-diet

The low FODMAP-diet was developed by a group of gastroenterology researchers at Monash University in Australia to manage IBS symptoms (Gibson et al., 2007). Dietary restrictions of fermentable short-chain carbohydrates effectively reduced the absorption of osmotically active short-chain carbohydrates in the small intestine, thus preventing the accumulation of luminal water and luminal gas production by colonic fermentation (Gibson & Shepherd, 2009). Strong evidence has supported the efficacy of a low FODMAP-diet for the management of GI-related diseases (e.g., IBS, fructose malabsorption) with positive effects in relieving overall GI symptoms (Shepherd & Gibson, 2006; Geary et al., 2009; Staudacher et al., 2011; Halmos et al., 2014). The effect is dose-dependent; that is, highly associated with the amounts of FODMAPs ingested, especially fructose or fructans (Shepherd et al., 2008).

The cut-off levels of different subgroups of FODMAPs and the main food sources (Table 1) provided a dietary guideline for IBS patients and adherence produced significant improvements in GI symptoms (Varney et al., 2017). A low FODMAP-diet should contain less than 0.5 g total FODMAPs per meal (Halmos et al., 2014).

Table 1 Cut-off levels of FODMAPs (per single serve)

Individual FODMAPs	Main Sources	Grams per serve (Individual food)
Fructose	Apple, pear, watermelon, asparagus, honey, corn syrup	< 0.15 g*
Lactose	Milk, yoghurt, cheese, ice cream	< 1.0 g
Fructans, FOS	Wheat, rye, barley, garlic, onion	< 0.2 g
GOS	Beans, legumes, lentils	< 0.3 g
Polyols	Blackberry, peach, apricot, apple, sorbitol, mannitol, xylitol	< 0.4 g

*Fructose in excess of glucose = fructose - glucose; FOS = fructo-oligosaccharides; GOS = galacto-oligosaccharides (Varney et al., 2017).

2.3.3 Combination of Gluten-free diet and low FODMAP-diet

Methods have been developed to quantify and characterise the contents of FODMAPs in different types of foods to provide effective dietary guidelines for affected patients to manage GI symptoms (Biesiekierski et al., 2011; Prichard et al., 2016; Tuck et al., 2018). The results revealed that GF products (e.g., bread, pasta) generally have reduced amounts of fructans and oligosaccharides and low levels of FODMAPs compared to gluten-containing products (Muir & Gibson, 2013). This is probably due to the co-existence of gluten and fructans in grains and cereals (Muir et al., 2019).

Greater symptomatic improvements can be achieved by a combination of a GF-diet and low FODMAP-diet for patients with functional GI diseases (Piacentino et al., 2014; Roncoroni et al., 2018; Usai-Satta et al., 2020). Roncoroni et al. (2019) found that nutritional intervention with a low FODMAP-diet for CD patients already on a GF-diet significantly reduced typical GI symptoms compared with patients who only followed a regular GF-diet. GF-diets containing high levels of FODMAPs can induce GI symptoms in treated CD patients (Roncoroni et al., 2018). Therefore, a low FODMAP-diet can have beneficial effects for patients with GI-related diseases who are on a GF-diet but still present with persistent GI symptoms.

2.4 Gluten-free Bread

Demand for GF products continues to increase because of improved diagnostic methods for CD and NCGS, and health concerns of consumers (Gallagher, 2008). However, due to the absence of the viscoelastic properties of gluten, GF breads are generally poor in overall quality with low crumb volume, rapid staling rate, and not well accepted by the majority of the consumers (Gallagher, Gormley & Arendt, 2003). Hence, GF formulations and technologies to improve bread quality, fortified ingredients or nutrients to enhance the nutritional values of bread, or addition of natural preservatives to increase the shelf-life of GF bread products are now available (Gallagher et al., 2004; Moroni, Dal Bello & Arendt, 2009; Arendt & Moroni, 2013; Oshea et al., 2014; Nionelli & Rizzello, 2016). However, production of GF breads of good quality still remains the biggest challenge for bread manufacturers due to a lack of low-cost alternatives and applications (Arendt & Moroni, 2013).

2.4.1 Gluten

Gluten is the major storage protein composite of wheat grain constituting approximately 80-85 % of the total proteins in wheat (Arendt et al., 2008). Gluten proteins play a crucial role in forming the strong, cohesive dough capable of trapping gas and production of palatable bread products. They are found in the starchy endosperm of wheat grain and their function is to nourish the embryo by providing nitrogen and amino acids for germination (Van Der Borgh et al., 2005; Wieser et al., 2014). When the grain matures, the gluten protein bodies become disrupted and coalesce to form a continuous matrix surrounding the starch granules (Shewry et al., 1995). The matrix contributes to the development of the continuous gluten network when wheat flour is mixed with water and kneaded mechanically.

Gluten proteins are insoluble in water or dilute salt solutions and can be classified into two functional proteins, gliadins (wheat prolamins) and glutenins (wheat glutelins) (Lindsay

Lindsay & Skerritt, 1999). Gliadins are monomeric proteins comprising 40-50 % of total flour protein content, which contain single-chain polypeptides with intra-chain cysteine disulphide bonds resulting in the globular nature of gliadins (Cornell, 2003). The molecular weights (MW) of gliadins vary from 30,000 to 55,000, and they can be distinguished into four groups: α -, β -, γ -, and ω -gliadins based on their electrophoretic mobility at low pH (Khatkar et al., 2002). The amino acid composition of gliadins contains extremely high levels of glutamine (~ 35 %), high levels of proline (~ 20 %), low levels of charged amino acids (arginine, lysine, histidine, aspartic acid and glutamic acid), as well as low amounts of cysteine (~ 3 %) (Cornell, 2003). Upon hydration, gliadins impart the viscous component to the viscoelastic characteristics of gluten, contributing to the extensibility and viscosity of the dough (Pomeranz, 1988; Don et al., 2003).

Glutenins are heterogeneous polymeric proteins linked with inter- and intra-molecular disulphide bonds, making up 30-45 % of wheat flour proteins. Glutenins can form the elastic backbone of gluten with a high MW of between 50,000 to 10 million (Wieser, 2007). Two classes of glutenin subunits, high-molecular-weight glutenin subunits (HMW-GS; MW 65,000 to 90,000) and low-molecular-weight glutenin subunits (LMW-GS; MW 30,000 to 60,000), are present in wheat when using reducing agents which break down the glutenin disulphide bonds (Goesaert et al., 2005). Glutenins have a similar amino acid composition to gliadins, comprising high glutamine (~ 30 %) in addition to proline (~ 13 %), and lower amounts of charged amino acids. Higher levels of glycine, but lower levels of isoleucine, phenylalanine, and valine have been reported in HMW-GS compared with LMW-GS (Cornell, 2003). When glutenins are hydrated, they are predominantly responsible for forming a continuous polymeric network structure, which provides elasticity, tenacity and strength (resistance to deformation) to the dough (MacRitchie, 1980).

2.4.2 The role of gluten in bread-making

During dough mixing, wheat flour is mixed with water and mechanically kneaded to form a dough, which disrupts the discrete masses of gluten proteins resulting in a continuous cohesive and viscoelastic gluten network (Singh & MacRitchie, 2001). Gliadin proteins act as plasticisers and interact with glutenin's polymeric network through hydrophobic and hydrogen bond linkages, providing plasticity and viscosity to the dough system (Van Der Borghet et al., 2005). The gluten network is capable of encapsulating gas or carbon dioxide (CO₂) (produced during fermentation and oven-rise), starch granules and other filler materials such as bran, contributing to loaf volume and crumb structure of the breads (Arendt et al., 2008; Scanlon & Zghal, 2001).

The physical characteristics of the dough (extensibility, mixing sensitivity, gas holding ability) are influenced by the relative proportions of gliadins and glutenins present in the dough. A higher glutenin content, imparting greater dough strength allows the dough to rise and improves the loaf volume (MacRitchie, 1987). In contrast, a higher proportion of gliadins, results in higher viscosity and an increased degree of softening of the dough, leading to poor performance during baking (Barak et al., 2014). The correct balance of extensibility and elasticity of the dough is necessary to produce bread of good quality (MacRitchie, 1987). Insufficient elasticity of the dough impairs gas retention, whereas excessive elasticity of the dough limits the dough expansion (Shewry et al., 1995).

During baking, coagulation of gluten induced by heating causes denaturation of gliadins and glutenins (Wang, Jin & Xu, 2015). This dramatically changes the hydrophobicity of the protein surface, increases the cross-linking and polymerisation of gluten polymers, and interchange reactions of sulphhydryl/disulphide bonds (Schofield et al., 1983; Lefebvre, Popineau & Cornec, 1993; Guerrieri et al., 1996). This results in the typical porous, spongy and elastic crumb

structure of breads with gelatinised starch granules and enclosed fibre fragments (Durrenberger et al., 2001; Ortolan & Steel, 2017).

2.4.3 The challenge of making GF bread

Absence of gluten significantly impairs the quality of the breads, as GF dough is more similar to a batter than dough, which cannot retain gas produced during fermentation due to its lack of cohesiveness and elasticity (Arendt & Moroni, 2013). This results in high permeation of gas and failure to maintain the bread structure (Goesaert et al., 2005). Removal of gluten also impairs the water-holding capacity of the breads, leading to early crumbly structure and rapid staling. Thus, GF breads are generally characterised with low specific volume, high crumb hardness, pale light crust, poor taste and flavour, and short shelf life (Gallagher, Gormley & Arendt, 2003; Gallagher et al., 2004; Hager et al., 2012; Matos & Rosell, 2012). Furthermore, as most GF breads are made with starch and are not fortified, they do not have adequate amount of essential nutrients, such as dietary fibre, minerals, folate, and vitamins B (Arendt et al., 2008), which contributes to nutritionally unbalanced diets of patients with CD or other gluten-related GI disorders who are on a strict GF-diet (Bardella et al., 2000; Thompson, 2000; Yazynina et al., 2008).

To produce GF breads with good baking quality and sensory characteristics, alternative flours, ingredients or additives which mimic the functionalities of wheat flour for bread-making have been studied (Gallagher et al., 2004). In the last decades, promising improvements in the quality of GF breads have been achieved by utilisation of permitted flours and legumes (e.g., rice, maize, sorghum, oat flours; chickpea, soya, and lentil), incorporation of nutrient dense ingredients such as whole grain and pseudocereals (e.g., buckwheat, amaranth, and quinoa), addition of starches, hydrocolloids (e.g., carboxymethyl cellulose, guar gum, and xanthan gum), emulsifiers, shortenings (e.g., butter and vegetable oil), proteins (e.g., egg proteins and dairy proteins) or enzymes (e.g., transglutaminase and glucose oxidase), and use of novel

technologies (e.g., sourdough fermentation and high hydrostatic pressure) (Anton & Artfield, 2008; Kohajdová, Karovičová & Juszczak, 2009; Moroni, Dal Bello & Arendt, 2009; Zannini et al., 2012; Oshea et al., 2014; Foschia et al., 2016). However, these alternatives inevitably increase the cost of GF bread production and the analysis of additives of the products. Thus, production of GF breads of superior quality and with good consumer acceptability still presents a challenge to bread manufacturers (Arendt & Moroni, 2013).

2.5 Sourdough Bread

The use of sourdough as a natural starter for bread leavening is considered the oldest form of biotechnological process (Röcken & Voysey, 1995; Chavan & Chavan, 2011). Sourdough is made from a mixture of flour (e.g., wheat, rye, rice, etc.), water, and possibly with other ingredients (e.g., salt) that are fermented by spontaneous LAB and yeasts introduced from the flour or baking environment (Corsetti & Settanni, 2007; Nionelli & Rizzello, 2016). During sourdough fermentation, LAB are mainly responsible for acidification through production of lactic and acetic acids, which confer the unique flavour and sour taste to the bread (De Vuyst & Neysens, 2005). Whereas yeasts primarily contribute to leavening through production of CO₂ from alcoholic fermentation, resulting in increased bread volume (Corsetti, 2013; De Vuyst et al., 2014). A general procedure for sourdough bread production is outlined in Figure 1.

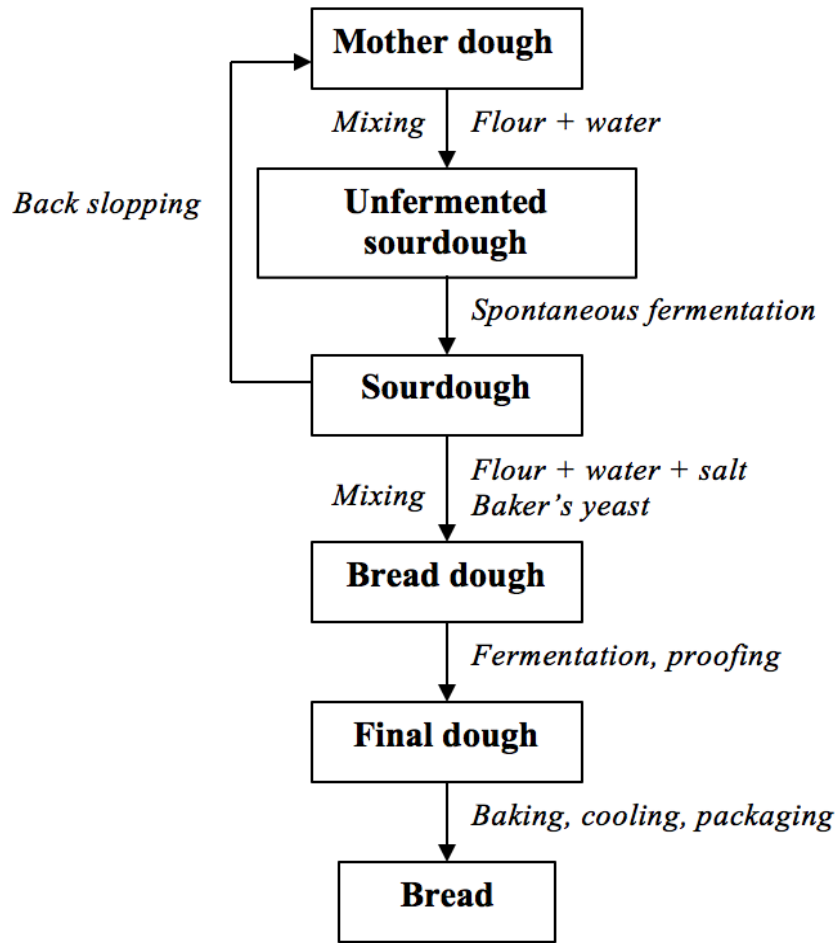


Figure 1 General production steps of sourdough bread (Hansen & Schieberle, 2005)

2.5.1 Classification of sourdough fermentation

Sourdough fermentation can be classified into three types, type I, II, and III (De Vuyst & Neysens, 2005; Corsetti, 2013; Siepmann et al., 2018). Type I sourdough represents the traditional sourdough technique that involves refreshing starter culture by addition of fresh flour and water at ambient temperatures (< 30 °C) used for dough leavening, without addition of baker's yeast *Saccharomyces cerevisiae* (*S. cerevisiae*). The repeated reinoculation process from a previous batch is known as backslopping, which keeps the sourdough microorganisms in a continuous state of growth with high metabolic activities (De Vuyst & Vancanneyt, 2007). At present, type I sourdough is still the most widely used method for traditional bread

production, because it improves the texture, flavour and shelf life of the bread, and also enhances the nutritional and functional properties of the bread products (Gobbetti et al., 2018).

Type II, or industrial liquid sourdoughs are generally used as dough acidifiers during bread-making to enrich the aroma and flavour of the breads, characterised by long fermentation periods (up to 5 days) with high concentrations of microbial inoculation produced in large-scale silos or tanks at a higher fermentation temperature ($> 30\text{ }^{\circ}\text{C}$) to shorten the fermentation process (Decock & Cappelle, 2005). Addition of baker's yeast is required for type II sourdoughs to leaven the final dough, as strong sourdough acidification may inhibit the growth of yeast (Corsetti & Settanni, 2007).

Type III, or industrial dried sourdoughs are similar to type II sourdoughs with the exception that are dried or stabilised by pasteurisation after preparation. Yeasts are rarely found in this type of sourdough due to the high drying temperature, so the addition of baker's yeast is also required. Type III sourdoughs are mainly used for industrial baking as their quality is more consistent compared to other types of sourdoughs and convenient for commercialisation, producing breads with more flavour properties and consistent quality (Chavan & Chavan, 2011).

2.5.2 Sourdough microbiota

The microbiota of sourdough is determined by endogenous and exogenous ecological factors (Vogelmann & Hertel, 2011). Endogenous factors are mainly associated with the microbial and chemical composition of the dough, including the original microbial ecology of the flour, endogenous enzyme activities, carbohydrates and nitrogen sources within the flour, and presence of growth inhibitors (Gobbetti et al., 2008). Exogenous factors are determined by the process parameters applied during fermentation, such as dough yield, fermentation time, fermentation temperature, oxygen level, salt level, the composition of the starter cultures, and the number of propagation steps (Hammes & Gänzle, 1998). If these factors are kept constant

for a long period, their interplay will create a distinct selection of different genera and species of LAB and yeasts that are derived from the flour and adapted to the environment (Gobbetti, 1998). In order to achieve optimum activities and maintenance, the ratio of LAB to yeasts should be around 100:1, with higher cell densities of LAB (10^7 to 10^9 CFU/g) than yeasts (10^5 to 10^7 CFU/g) (De Vuyst & Neysens, 2005).

More than 60 species of LAB and over 25 species of yeasts have been previously isolated from sourdoughs made from different origins (Gobbetti et al., 2008; De Vuyst et al., 2014). The main species of LAB (more than 23 species) isolated from sourdoughs belong to the genus *Lactobacillus*, but species from the *Leuconostoc*, *Pediococcus* and *Weissella* are also frequently found in sourdoughs (De Vuyst & Neysens, 2005). The predominant species of LAB found in cereal and pseudocereal sourdoughs are *L. sanfranciscensis*, *L. fermentum*, *L. plantarum*, *L. pontis*, *L. plaralimentarius*, *L. spicheri*, *L. fructivorans*, *L. helveticus*, and *L. delbrueckii* (De Vuyst & Vancanneyt, 2007).

The adaptability of yeasts within the sourdough ecosystem depends on the type of grain used, dough hydration, dough temperature, and the extent of acidification (Emerald et al., 2016). The majority of yeasts isolated from mature sourdough belong to the genera of *Saccharomyces* and *Candida* (Hammes & Gänzle, 1998). The typical yeasts found in sourdough include *S. cerevisiae*, *S. exiguous*, *C. milleri*, *C. holmii*, and *Issatchenkia orientalis* (Vernocchi et al., 2004), as well as other species such as *Debaryomyces hansenii*, *Torulaspora delbrueckii*, *Pichia anomala*, *P. membranifaciens*, and *P. saitoi* (Gobbetti et al., 1994; Succi et al., 2003; Emerald et al., 2016).

2.5.3 Metabolism of sourdough microorganisms

Sourdough fermentation is a complex process based on the metabolic activities of sourdough microbial communities (LAB and yeasts), which directly or indirectly affect the organoleptic

and technological characteristics of the bread products (Gobbetti et al., 2008). Different species of LAB and yeasts utilise different carbohydrate and nitrogen substrates as their energy source for growth and metabolism, resulting in the production of different metabolites and aromatic compounds (Diowksz & Ambroziak, 2006). The performance of sourdough is also influenced by the interaction between LAB and yeasts (De Vuyst et al., 2014). Therefore, high sourdough acidification and production of full aroma can be achieved by using sourdough starters containing a mixture of selected strains of LAB and yeasts (Chavan & Chavan, 2011; Corsetti, 2013; De vuyst, Van Kerrebroeck & Leroy, 2017).

2.5.4 Carbohydrate metabolism by sourdough lactic acid bacteria

Lactic acid bacteria are characterised by two main hexose monosaccharide fermentation pathways, which are known as homolactic and heterolactic pathways (Axelsson, 2004; Gänzle, Vermeulen & Vogel, 2007). Based on these two pathways, LAB have been divided into three categories according to their different capabilities to utilise sugars: homofermentative, heterofermentative and facultative heterofermentative (Axelsson, 2004). Homofermentative LAB (*Lactococcus* sp., *Pediococcus* sp., *Streptococcus* sp., and certain *Lactobacillus* sp.) ferment hexoses via the glycolytic Embden-Meyerhoff Parnas (EMP) pathway, to produce mainly lactic acid by anaerobic metabolism. Heterofermentative LAB (*Leuconostoc* sp., *Weisella* sp., *Oenococcus* sp., and some *Lactobacillus* sp.) metabolise hexoses using the phosphoketolase pathway (also known as the pentose phosphate pathway), produce lactic acid as well as significant amounts of CO₂, acetic acid and/or ethanol as end-products due to the presence of additional substrates acting as electron-acceptors. Facultative heterofermentative LAB can ferment sugars through both pathways, predominantly the pentose phosphate pathway in the absence of fermentable carbon sources (Hutkins, 2006). Each metabolic category of LAB predominantly present in sourdough breads are shown in Table 2.

Table 2 Homofermentative, heterofermentative and facultative heterofermentative LAB in sourdough bread*

Homofermentative LAB	Heterofermentative LAB	Facultative heterofermentative LAB
<i>L. amylovorus</i>	<i>L. acidifarinae</i>	<i>L. plantarum</i>
<i>L. acidophilus</i>	<i>L. brevis</i>	<i>L. pentosus</i>
<i>L. delbrueckii</i>	<i>L. fermentum</i>	<i>L. casei</i>
<i>L. farciminis</i>	<i>L. frumenti</i>	<i>L. paralimentarius</i>
<i>L. mindensis</i>	<i>L. reuteri</i>	<i>L. alimentarius</i>
<i>L. johnsonii</i>	<i>L. rossiae</i>	
	<i>L. sanfranciscensis</i>	
	<i>L. zymae</i>	

*Source: De Vuyst and Neysens (2005); Zhou and Therdthai (2012).

In homofermentative pathways (glycolysis or EMP pathway), homofermentative LAB convert one glucose molecule to two lactic acid molecules to release two molecules of ATP (Figure 2) (Aarnikunnas, 2006; Von Wright & Axelsson, 2011). Glycolysis starts from the phosphorylation of glucose to glucose-6-phosphate by glucokinase. Glucose-6-phosphate is converted to fructose-6-phosphate by phosphoglucose isomerase through isomerisation. Fructose-6-phosphate is then phosphorylated by phosphofructokinase into fructose-1,6-diphosphate, which further splits into glyceraldehyde-3-phosphate (GAP) and dihydroxyacetone phosphate (DHAP) (also converted into GAP) by the catalysation of fructose-1,6-diphosphate aldolase. Glyceraldehyde-3-phosphate is oxidised to pyruvate in two steps of substrate-level phosphorylation, then pyruvate is finally reduced to lactic acid by lactate dehydrogenase (LDH), coupled by the oxidation of NADH to NAD⁺ (Axelsson, 2004).

Figure 2 Homolactic fermentation (glycolysis, or EMP pathway) by homofermentative LAB
(Aarnikunnas, 2006)

Enzymes: 1. glucokinase; 2. fructose-1,6-diphosphate aldolase; 3. pyruvate kinase; 4. Lactate dehydrogenase.

In heterofermentative pathways (phosphoketolase pathway, or pentose phosphate pathway) (Figure 3), heterofermentative LAB also produce CO₂, acetic acid or ethanol through conversion of glucose by glucose-6-phosphate dehydrogenase and 6-phosphogluconate dehydrogenase. The phosphoketolase pathway initiated from phosphorylation of glucose, then one glucose-6-phosphate molecule is dehydrogenated by the enzyme glucose-6-phosphate dehydrogenase to 6-phosphogluconate, which is further decarboxylated to ribulose-5-phosphate and to produce CO₂. Ribulose-5-phosphate is isomerised to xylulose-5-phosphate, then cleaved into GAP and acetyl-P by phosphoketolase. Subsequently, GAP is metabolised by LAB to produce lactate by homolactic fermentation, whereas acetyl-P is converted to acetate or dephosphorylated to acetyl coenzyme A (acetyl-CoA). Acetyl-CoA is further converted to acetaldehyde by acetaldehyde dehydrogenase, and finally reduced to ethanol by alcohol dehydrogenase (Von Wright & Axelsson, 2011).

Most sourdough *Lactobacillus* spp. can ferment sucrose, maltose, hexoses, and pentoses, although some species show different preferences (Martínez-Anaya, 2003). For example, *L. plantarum* is fructose-negative and therefore it grows more rapidly in glucose and maltose than in fructose. Sucrose metabolism is based on the permease system of the cells and is initiated by the enzyme sucrose hydrolase to split sucrose into glucose and fructose, or in certain LAB related to the enzyme sucrose-6-phosphate hydrolase which cleaves sucrose-6-phosphate into fructose and glucose-6-phosphate, which can then enter the metabolic pathway (Thompson & Chassy, 1981). Metabolism of maltose is also mediated by specific enzymes, such as the enzyme maltose phosphorylase which enables *L. sanfranciscensis* to convert maltose to glucose-1-phosphate and glucose (Stolz et al., 1993). Metabolism of pentoses only occurs by heterolactic fermentation; pentoses are transported into the cells by specific permeases and form ribulose-5-phosphate or xylulose-5-phosphate by phosphorylases and isomerases, then enter the phosphoketolase pathway without production of CO₂ with no dehydrogenation steps. Acetyl-P is only converted to acetate and forms ATP by acetate kinase, therefore ethanol is not produced (Kandler, 1983; Von Wright & Axelsson, 2011).

Figure 3 Heterolactic fermentation (phosphoketolase pathway) by heterofermentative LAB
(Aarnikunnas, 2006)

Enzymes: 1. 6-phosphogluconate dehydrogenase; 2. phosphoketolase; 3. Alcohol dehydrogenase.

2.5.5 Yeast carbohydrate metabolism

The main carbohydrate substrates in flour that can be metabolised by yeast are sucrose, glucose, fructose, and maltose (De Vuyst et al., 2016). Invertase, an enzyme secreted by yeast cells, can rapidly break down sucrose into glucose and fructose during the initial dough mixing and the early stages of fermentation (Rodrigues, Ludovico & Leão, 2006). Yeast invertase is also capable of hydrolysing short-chain oligosaccharides (e.g., fructans, composed of fructose and glucose molecules) originating from flour (Bacon, 1954; Koch, Smith & Geddes, 1954). Most of the yeasts identified in typical sourdough breads (e.g., *S. cerevisiae*) are facultative-fermentative yeasts, which are capable of both aerobic respiratory metabolism and anaerobic fermentative metabolism (Figure 4) (De Vuyst et al., 2016).

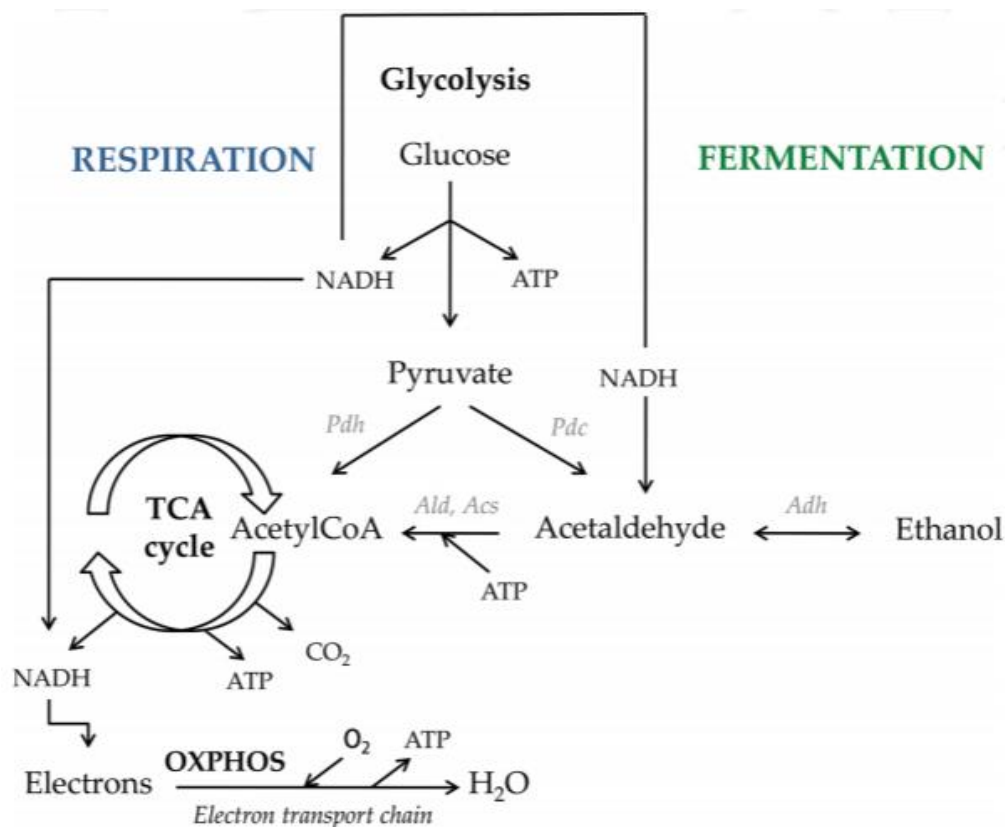


Figure 4 Carbohydrate metabolism by yeast (García et al., 2016)

TCA cycle = tricarboxylic acid cycle; OXPHOS = oxidative phosphorylation; Enzymes: Pdh = pyruvate dehydrogenase; Pdc = pyruvate decarboxylase; Ald = aldehyde dehydrogenase; Acs = acetyl-CoA synthetase; Adh = alcohol dehydrogenase.

The primary carbohydrate metabolism of yeast is glycolysis, where one molecule of glucose is converted into pyruvate, ATP and NADH (Pronk, Yde Steensma & Van Dijken, 1996). When oxygen is available, pyruvate produced from glycolysis is converted into acetyl-CoA through decarboxylation catalysed by pyruvate dehydrogenase (Kresze & Ronft, 1981). The acetyl-CoA is then oxidised by transferring the acetyl group into CO₂ through the tricarboxylic acid (TCA) cycle and oxidative phosphorylation (Pronk, Yde Steensma & Van Dijken, 1996).

In the absence of oxygen, pyruvate enters the alcoholic fermentation pathway and is decarboxylated by pyruvate decarboxylase to acetaldehyde, which then reduced into ethanol by alcohol dehydrogenase through oxidation of NADH released from glycolysis (Rodrigues, Ludovico & Leão, 2006). Acetyl-CoA is the major metabolite within the TCA cycle, and it can also be formed through oxidation of acetaldehyde that is produced from alcoholic fermentation to acetate catalysed by acetaldehyde dehydrogenase (García et al., 2016). Acetate can be converted into acetyl-CoA by acetyl-CoA synthetase (Pronk, Yde Steensma & Van Dijken, 1996).

When sufficient carbohydrate substrates and oxygen are present, alcoholic fermentation is the predominant metabolic pathway of yeast over respiration (De Deken, 1966). When carbohydrate substrates are exhausted, yeast switches alcoholic fermentation to full respiration, which slows the growth rate by aerobic respiration using ethanol (Heitmann, Zannini & Arendt, 2018). CO₂ and ethanol are the dominant metabolic products produced by yeast metabolism, which have the greatest impact on the quality characteristics of bread (Ali et al., 2012). The CO₂ produced by yeast leads to dough leavening and contributes to bread volume, and the ethanol results in a decrease in extensibility and extensional viscosity of dough and subsequently evaporates during baking (Horstmann et al., 2018).

2.6 Characterisation of Sourdough Parameters

The composition of sourdough microbiota determines metabolite production and sourdough characteristics, which are reflected in the quality of bread product (Figure 5). The performance of sourdough is influenced by a series of factors, such as acidification properties of LAB (production of lactic and acetic acid), microbial composition of the starter cultures (species and number of LAB and yeast, ratio, performances), and the interactive effects determined by the process conditions (flour type, fermentation time, temperature, dough yield, oxygen, number of refreshments) (Hansen, 2004; Arendt et al., 2007; Chavan & Chavan, 2011).

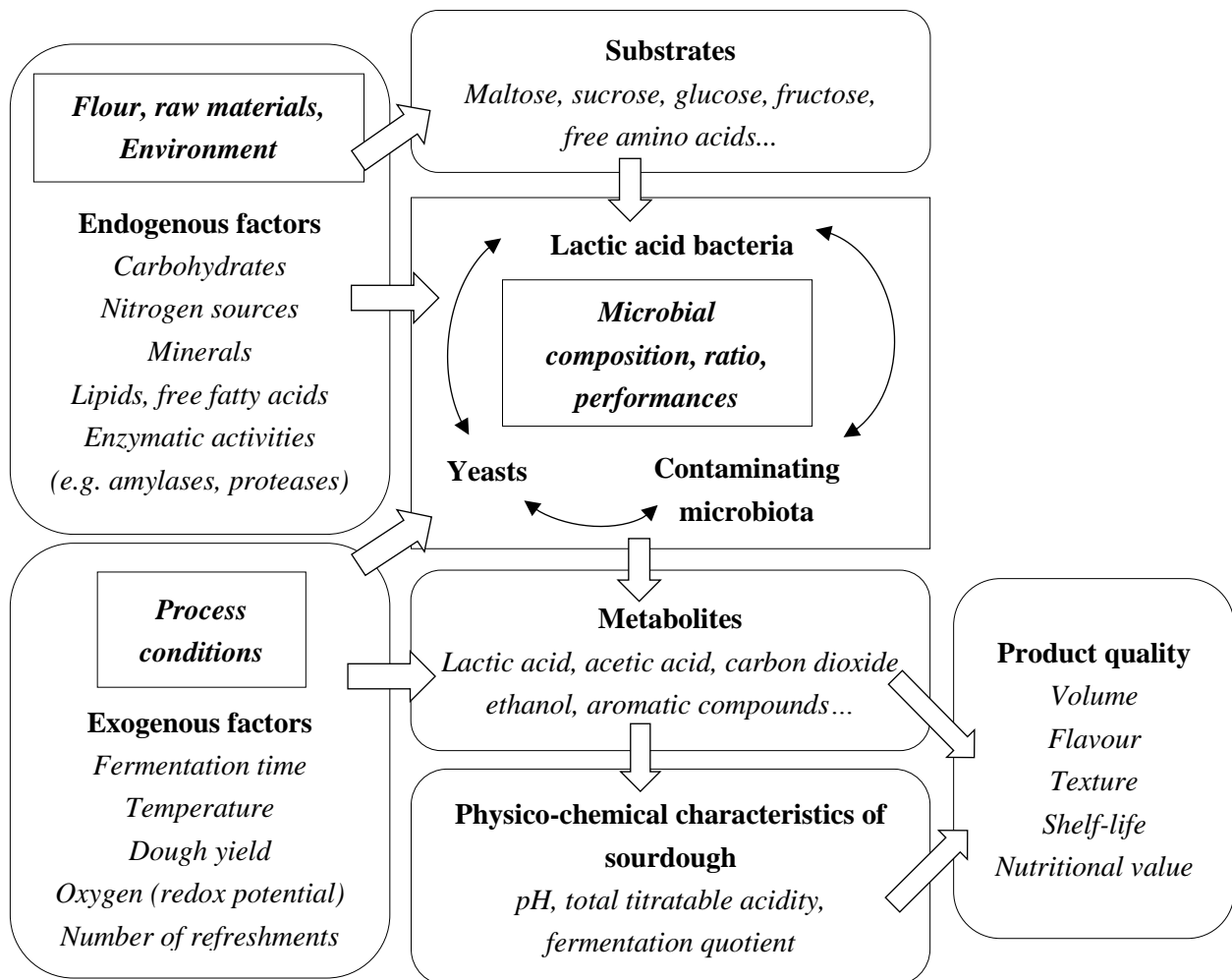


Figure 5 Factors influencing the composition and metabolite production of sourdough microbiota, characteristics of sourdough, and product quality (Hammes & Gänzle, 1998; De Vuyst et al., 2017)

2.6.1 pH and total titratable acid (TTA)

The pH and total titratable acid (TTA) are important sourdough parameters, which can be used as indices for evaluating the development of sourdough fermentation. The pH of typical sourdoughs made from wheat and rye is in the range of 3.5-3.8 (Hansen, 2004). In contrast the TTA for sourdoughs varies between 8-26 depending on the type of flours used for bread production, as the amount of carbohydrate substrates are different. For example, sourdoughs made with low extraction flour have a lower TTA (8-11), sourdoughs made with whole meal flour have a higher TTA (16-22), and rye sourdoughs generally have a TTA of 15-26 (Lund, Hansen & Lewis, 1989; Brümmer & Lorenz, 1991; Hansen & Hansen, 1994; Spicher & Stephan, 1999). During sourdough fermentation, pH decreases and the TTA of sourdough increases as the amount of organic acids increase (Hansen, 2004). The decrease in pH is mainly due to the lactic acid produced by sourdough LAB (Leenhardt et al., 2005). The acetic acid generated during sourdough fermentation only slightly impacts on the pH of sourdough but affects the sensory acidity and structure formation of the final bread (Valjakka et al., 2003; Corsetti & Settanni, 2007).

2.6.2 Fermentation quotient (FQ)

The fermentation quotient (FQ), which is defined as the molar ratio of lactic acid and acetic acid produced during fermentation, indicates the metabolite profile of LAB that are mainly determined by the composition of the starter cultures (Corsetti, 2013). Sourdoughs with obligate homofermentative and facultative heterofermentative LAB as predominant species produce relatively lower levels of acetic acid, resulting in a higher FQ (Loenner & Ahrne, 1995). Endogenous (e.g., flour type, substrate concentration, etc.) and exogenous factors (e.g., fermentation temperature, dough yield, etc.) also affect the FQ (Corsetti, 2013). The FQ decreases with decreased dough yield and fermentation temperature, as these factors influence the acidification rate of the sourdough (Spicher & Rabe, 1980; Spicher & Stephan, 1999). The

lower the dough yield or temperature, the slower the acidification, resulting in lower levels of lactic acid and more acetic acid being produced (Chavan & Chavan, 2011). The correct FQ value is very important for the flavour development of the bread and an FQ in the range of 4-9 is preferred as the bread will have a mild acid taste and flavour, whereas bread with a low FQ will have a strong acid flavour, which is not considered desirable for most bread products (Hansen, 2006).

2.6.3 Flour type

Flour type markedly influences the progress and outcome of sourdough acidification, as the production of desirable metabolites by sourdough LAB and yeasts depend on the metabolisable substrates, nutrients and the extraction rate of the initial flours (Chavan & Chavan, 2011). Higher amounts of acids are produced in wholemeal flour sourdough than low extraction flour (Hansen, 2004), as wholemeal flour has higher α -amylase activity especially in the bran fraction that hydrolyses starch into maltose, which is then converted to glucose providing more carbohydrate substrates for LAB metabolism (Martínez-Anaya, 2003). The microbial composition and diversity of the sourdough microbiota is influenced by the amount of substrates that can be utilised, which varies with the type of cereal (Hammes & Gänzle, 1998). Endogenous enzymes within the flour, such as α -amylase and peptidase, also influence the growth of sourdough microbiota as they play an important role in the production of fermentable carbohydrates and free amino acids for microbial metabolism (Hansen, 2006; De vuyst et al., 2017).

2.6.4 Dough yield

The dough yield (DY) is the proportion between flour and water used for baking. Dough yield = (flour weight + water weight) \times 100 / flour weight (Chavan & Chavan, 2011). The DY indicates the consistency of sourdough and the amount of water added in the dough formula

(Gianotti et al., 1997). The DY is highly correlated with the sourdough flavour profile (Martínez-Anaya, de Barber & Esteve, 1994), with a lower DY having a firmer texture and producing more acetic acid and less lactic acid (Chavan & Chavan, 2011). The DY also influences the acidification rate of the sourdough, with a higher DY having a faster acidification rate, because of better diffusion of the organic acids produced during sourdough fermentation (Spicher & Stephan, 1999).

2.6.5 Fermentation time and temperature

Typical sourdough fermentation time is around 8-24 hours at 25-35 °C (Hansen, 2004; Corsetti, 2013). The temperature of sourdough fermentation affects the propagation of LAB and yeasts and the acidification rate, as the optimum temperature for microbial growth and acidification is different (Hansen, 2006), being around 30-35 °C for LAB (Spicher & Stephan, 1999), and between 26-32 °C for yeast (Diowksz & Ambroziak, 2006). Sourdough fermentation at higher temperatures (28-35 °C) accelerates the activities of sourdough LAB, producing more lactic acid than acetic acid, but inhibits the development of yeast. Therefore, the final bread is characterised by a relatively mild acidity flavour and lower volume (Corsetti, 2013; De vuyst et al., 2017). However, prolonged fermentation times at low temperatures between 20-27 °C is recommended as this will promote the metabolic activities of yeasts as well as maintain the development of LAB, thus not only producing CO₂ for rising the dough but also generate aromatic precursors for flavour development, resulting in bread with increased volume and flavour (Poitrenaud, 2003). While the amount of lactic acid produced during sourdough increases with increasing temperature, however, the influence of temperature on the production of acetic acid is negligible (Hansen, Lund & Lewis, 1989).

2.7 Sourdough in GF Bread-making

The exploitation of sourdough for improving the quality of wheat-containing breads is well-established and applied in the baking industry (Clarke & Arendt, 2005; Chavan & Chavan, 2011). Similarly, sourdough microorganisms possess unique metabolic and enzymatic activities capable of improving the quality of GF breads (Arendt et al., 2007). They can produce exopolysaccharides (EPS) which improve bread structure, generate aroma compounds for bread flavour enhancement, hydrolyse starch to retard bread staling, produce anti-fungal compounds to improve the shelf life of breads, and generate bioactive compounds that enhance nutritional value and confer health benefits to breads (Gobbetti, 1998; Corsetti & Settanni, 2007; De Vuyst & Vancanneyt, 2007; Moore et al., 2007; Schober et al., 2007; Poutanen, Flander & Katina, 2009).

2.7.1 Production of exopolysaccharides (EPS)

LAB produce high molecular weight polymer EPS with physicochemical characteristics similar to commercial hydrocolloids that are externally added into bread formulations (Arendt & Moroni, 2013). EPS can be classified into two types based on their main-chain polymer composition: homopolysaccharides (HoPS) called glucans and fructans that have a single monosaccharide (glucose or fructose), and heteropolysaccharides (HePS) that consist of more than one type of monosaccharide (De Vuyst & Degeest, 1999). HePS are formed in very low amounts with minor effects in cereal and bakery products, therefore they are the dominant EPS useful in bread-making (Moroni, Dal Bello & Arendt, 2009). HoPS are synthesised by the action of extracellular enzymes glucansucrases or fructansucrase produced by sourdough LAB (Lacaze, Wick & Cappelle, 2007).

Application of sourdough fermentation with HoPS-producing LAB strains can be used to produce GF breads with improved structural properties (Waldherr & Vogel, 2009). Dough

acidification enhances the swelling of the polysaccharides, which mimic the structure-forming function of gluten network (Galle, 2013). The EPS produced by LAB during sourdough fermentation are capable of binding water and retaining gas, thereby increasing the specific volume of bread and inducing softness to the crumb (Moore, Dal Bello & Arendt, 2008).

Sourdough fermented with EPS-producing *Weissella* strains can be used as hydrocolloid replacers to improve the rheology of GF dough (Galle et al., 2010). These strains also produce small amounts of acetate, which can balance the negative effects of acidification and produce breads with favorable flavours and improved bread texture (Schwab et al., 2008). This is due to dextran produced by *Weissella* strains, which is capable of binding water and influencing the firmness of the bread (Wolter et al., 2014). The isomaltooligosaccharides and dextran produced by *Weissella* strains may be retained in the bread and provide additional nutritional value to the GF breads, by increasing the levels of prebiotic GOS (Schwab et al., 2008).

2.7.2 Production of aroma compounds

The highly appreciated flavour of sourdough breads is mainly attributed to the microbial and enzymatic activities of the yeast and LAB that convert carbohydrates, amino acids, and lipids into volatile compounds during fermentation (Mugula, Sorhaug & Stepaniak, 2003; Edema & Sanni, 2008; Moroni, Dal Bello & Arendt, 2009; Arendt & Moroni, 2013). Sourdough fermentation and lipid oxidation produce volatile metabolites such as acids, alcohols, esters, ketones and aldehydes responsible for the typical bread crumb odour. Whereas other flavour compounds such as pyrazines, pyridines, pyrroles, furan, acetaldehyde, generated during baking and caused by the Maillard reaction, caramelisation of sugars, and thermal degradation reactions, are particularly important for the crust odour of bread (Pico, Bernal & Gomez, 2015; Pétel, Onno & Prost, 2017). During sourdough fermentation, LAB-induced acidification creates favorable acidic conditions for endogenous protease activation that degrade the proteins in flours (Thiele, Gänzle & Vogel, 2002). The peptides liberated by proteolysis are further

hydrolysed into free amino acids through the activities of intracellular peptidases produced by LAB (Gobbetti et al., 2005; Gänzle et al., 2008). The large amounts of free amino acids produced by proteolysis can either contribute to flavour compounds directly or undergo further enzymatic catabolism or thermal degradation during baking, resulting in the production of volatile compounds (Nionelli & Rizzello, 2016).

The flavour development of sourdough bread is influenced by the microbial composition (Gobbetti, 1998). Homofermentative and heterofermentative LAB can be differentiated based on the non-volatile flavour compounds produced during fermentation. Both strains can metabolise hexoses, but homofermentative LAB produce lactic acid, whereas heterofermentative LAB produce lactic and acetic acids, CO₂ and ethanol (Hansen & Schieberle, 2005). With regards to the volatile metabolites produced during fermentation, homofermentative strains mainly produce diacetyl, hexanal and acetaldehyde, while heterofermentative strains synthesise aldehydes, ethyl acetate, and hexyl acetate (Damiani et al., 1996). The fermentation quotient is the most important factor affecting the aroma of sourdough breads (Corsetti & Settanni, 2007). The addition of *S. cerevisiae* with sourdough cultures containing *L. sanfranciscensis*, *L. plantarum*, *L. sanfrancisco* or *L. delbrueckii* can modify the volatile profiles of breads and produce more yeast-derived fermentation products, such as ethanol, 2- and 3-methyl-1-butanol and methylpropanol (Gobbetti, 1995a; Hansen & Hansen, 1996).

The types of flour used for GF bread-making affect the aromatic flavour of the final breads (Gobbetti et al., 1995), and along with starches (teff, rice, buckwheat, amaranth, quinoa, and corn starch) result in different aroma profiles (Pico et al., 2017). Higher levels of nonanal and 2,4-decadienal are present in rice and teff breads due to ethyl hexanoate, ethyl nonanoate, aldehydes as well as alcohols produced by fatty acid oxidation. Quinoa and amaranth breads are characterised by higher levels of aldehydes and alcohols (Pico et al., 2017).

Processing parameters, such as fermentation temperature and time also influence the development of volatile compounds (Hansen & Schieberle, 2005). The production of lactic acid increases with increased fermentation temperature, thereby affecting the fermentation quotient, and volatile profiles. The production of ethanol, 1-propanol, 2-methyl-1-propanol, and 3-methyl-1-propanol markedly increase when the fermentation temperature rises 25 to 30 °C, indicating that yeast fermentation is more favorable at a slightly higher temperature of around 30 °C (Gobbetti et al., 1995). In addition, production of sufficient volatile compounds requires a longer fermentation time (12-24 h), whereas with short fermentation periods (under 3 h), iso-alcohols produced by yeast fermentation account for the dominant volatile.

2.7.3 Control of staling in GF bread

Bread staling involves changes that occur in the crumb and crust of the bread after baking including changes to crumb firmness, loss of flavour, loss of bread freshness and crust crispness (D'apponia & Morad, 1981). The cause of bread staling is not a single effect and has been attributed to a series of physico-chemical events, including amylopectin retrogradation, moisture migration and redistribution, and interactions between protein and starch (Gray & Bemiller, 2003). GF breads stale quickly, as most are made from starch-based ingredients, and migration of moisture is easier in the absence of a gluten network (Gallagher et al., 2003). During cooling and storage, the amylose and amylopectin in bread realign themselves to form a semi-crystalline structure. Retrogradation of starch causes water to be expelled from the bread and the crumb becomes firm and stale, which is unacceptable to the consumers (Goesaert et al., 2009). Amylases are normally used in bread-making to reduce staling rate of bread and contribute to the production of dextrans that can interfere with starch retrogradation, thus prevent bread firmness (Schultz et al., 1952; Zobel & Senti, 1959).

Incorporation of sourdough in GF bread-making can retard the firming of bread and reduce the rate of staling (Corsetti et al., 1998a; Arendt et al., 2007; Moore et al., 2007). Production of

organic acids during sourdough fermentation accelerates the amylase and protease activities of the flour changing the starch and protein fractions, thus increasing bread volume and softness (Barber et al., 1992; Dal Bello et al., 2007; Tamani et al., 2013; Cappa et al., 2016). Additionally, proteolysis has a synergetic effect, increasing α -amylase activity by liberating water from the protein network, therefore reducing bread firmness and dryness (Schwimmer, 1981).

2.7.4 Improvement of shelf-life

Mould growth represents the major cause of bread spoilage which results in serious economic losses for the manufacturer as well as health concerns for the consumers due to the possibility of mycotoxin contamination (Legan, 1993). The development of mould is caused by post-processing contamination, from dust and mould spores distributed in the environment. Sourdough fermentation is known to prolong the shelf life of bakery products because of the production of anti-mould and anti-fungal substances by sourdough LAB. Sourdough-associated strains possess various anti-mould activities, mainly attributed to the presence of obligately heterofermentative *Lactobacillus* spp. (Corsetti et al., 1998b). The inhibitory substances produced by heterofermentative LAB during sourdough fermentation such as organic acids, ethanol, hydro peroxide, CO₂, diacetyl, and other substances (e.g., bacteriocins and antibiotic) can prevent the growth of spoilage mould (Röcken, 1996; Messens & De Vuyst, 2002; De Vuyst & Leroy, 2007).

The organic acids (acetic, caproic, formic, butyric, propionic, and n-valeric acids) produced by *L. sanfrancisco* can inhibit most common types of spoilage fungi *Penicillium*, *Fusarium*, *Aspergillus* and *Monilia* present in spoiled breads (Corsetti et al., 1998b). Strains of *L. plantarum* and *L. amylovorous* can produce antifungal compounds such as 4-hydroxyphenyllactic, 3-phenyllactic, hydroferulic and phloretic acids that act against the growth of several species of *Fusarium*, *Penicillium*, and *Aspergillus* (Lavermicocca et al., 2000; Lavermicocca et al., 2003; Dal Bello et al., 2007; Ryan et al., 2009; Axel et al., 2015). Strains

of *L. reuteri* can produce antibiotic reutericyclin which inhibit gram-positive LAB and yeast by releasing reuterin (3-hydroxypropionaldehyde), a compound with broad anti-microbial activity (Gänzle et al., 2000; Gänzle, 2004). Sourdough fermentation can prevent rope spoilage in bread induced by *Bacillus* spp. (Katina et al., 2002; Valerio et al., 2008). The production of organic acids and other effective anti-bacterial compounds by LAB strains *L. plantarum* and *P. pentosaceus* are capable of inhibiting the germination of *Bacillus* spores (Pepe et al., 2003).

Application of sourdough provides potential for natural biopreservative ingredients that can replace the use of additives in the production of GF breads, thus prolonging shelf life and improving quality (Garofalo et al., 2012). The addition of sourdough containing anti-fungal strain *L. plantarum* in GF breads significantly retarded the growth of pathogenic fungi *Fusarium culmorum* for up to 3 days (Moore, Dal Bello & Arendt, 2008).

2.7.5 Improvement of nutritional value and health benefits

Sourdough has been used to leaven GF breads made from amaranth, buckwheat, maize, millet, quinoa, and rice and it has gained popularity due to its effectiveness in improving the nutritional value and health benefits of GF breads (Moroni, Dal Bello & Arendt, 2008; Vogelmann et al., 2009; Nionelli & Rizzello, 2016). Sourdough fermentation does this by improving the bioavailability of minerals, regulating the levels of bioactive compounds, and reducing the digestibility of starch (Poutanen, Flander & Katina, 2009).

Cereal foods, especially bread, provide a good source of minerals, such as magnesium, calcium, zinc, iron, and phosphorus that are essential for human health. However, the absorption of minerals may be limited by the presence of anti-nutritional phytic acid in cereal grains. Phytic acid has a strong chelating capacity, which interferes with mineral absorption through forming insoluble phytate complexes with dietary cations (Bohn, Meyer & Rasmussen, 2008). Phytases are enzymes that can dephosphorylate phytate into lower inositol phosphate esters and free

inorganic phosphorus. Sourdough fermentation produces a favorable acidic environment (optimal pH for phytase activity is 4.5) that accelerates the activation of endogenous phytases in cereal flours (Fretzdorff & Brummer, 1992). Slight acidification (pH decrease to 5.5) induced by sourdough fermentation has been shown to result in breakdown of phytate by up to 70 % (Leenhardt et al., 2005). In addition, phytase activity is also present in some strains of sourdough-associated LAB and yeasts. The use of *S. cerevisiae* combined with selected sourdough LAB strains (e.g., *L. plantarum*, *Leuc. mesenteroides*, *L. sanfranciscensis* and *P. pentosaceus*) significantly decreased the phytic acid content in sourdough and increased the bioavailability of minerals (e.g., calcium, iron, zinc, magnesium and phosphorus) (Chaoui et al., 2003; Di Cagn et al., 2008; Cizeikiene et al., 2015).

Sourdough fermentation can also modify the bioavailability of several essential nutrients and bioactive compounds in grains, such as folate, thiamine, tocopherols and antioxidant like phenolic compounds (Liukkonen et al., 2003; Kariluoto et al., 2004). Increases in total folate content are mainly due to the synthesis of folates by yeast (Osseyi et al., 2001). The levels of thiamine and riboflavin have been reported to increase during prolonged yeast and sourdough fermentation (Ternes & Freund, 1988). Losses of tocopherols and tocotrienols have been observed during sourdough fermentation (Liukkonen et al., 2003; Batifoulier et al., 2005), which could be due to oxidation. Sourdough fermentation can increase the antioxidant activity, phenolic compounds and free amino acids in GF sourdough made with rye, quinoa, chickpea, amaranth or buckwheat flours, probably due to the breakdown of bound phenolics during fermentation and the synthesis of γ -aminobutyric acid (GABA) (Liukkonen et al., 2003; Coda, Rizzello & Gobbetti, 2010).

The metabolism of carbohydrates and proteins by sourdough microbiota plays an important role in increasing the digestibility of sourdough bread. During sourdough fermentation, the complex carbohydrates can be degraded into digestible simple sugars, and proteins are metabolised into amino acids and peptides (Siepmann et al., 2018). Organic acids produced

during sourdough fermentation such as lactic acid, acetic acid, and propionic acid reduce starch gelatinisation and accelerate the formation of resistant starch, thereby reducing the rate of starch digestion and lowering the glycemic index (Liljeberg, Lönner & Björck, 1995; Östman, 2003; Novotni et al., 2012).

2.8 FODMAP Content of Bread

Bread is a staple food in most countries and the major source of daily-consumed FODMAPs, therefore it is often implicated as the key dietary trigger for IBS symptoms (Laatikainen et al., 2016). The FODMAP content of bread varies depending on the type of flours or grains used for baking and the food processing conditions used (Biesiekierski et al., 2011). Other ingredients commonly used in bread-making may also increase the overall FODMAPs in breads, such as sweeteners (sources of fructose and fructans, e.g., coconut sugar, corn syrups, honey), fruit inclusions (high in fructose and fructans, e.g., blueberries, banana, raisin), nuts and seeds (sources of raffinose and stachyose, e.g., almonds, linseeds), and pseudo-cereals and legumes (high in raffinose and stachyose, e.g., quinoa, amaranth, chickpea) (Muir et al., 2009; Curiel et al., 2015).

The few studies which quantified the FODMAP content in breads, indicate that fructose and glucose are present in all types of breads (wheat, rye, spelt, GF). Fructans are the major FODMAPs in breads, with others including FOS (nystose and kestose), GOS (raffinose and stachyose), and sugar polyols (sorbitol and mannitol) also occurring (Biesiekierski et al., 2011; Whelan et al., 2011).

2.9 Development of Low FODMAP Bread

Development of palatable low FODMAP breads can be achieved by developing formulations with low FODMAP containing ingredients and grains (Varney et al., 2017), and implementing

specific bread-making processes such as yeast-based dough and longer fermentation (not less than 4 h) (Ziegler et al., 2016). Further reduction of FODMAPs can be obtained by prolonged sourdough fermentation or with specific strains of *Lactobacillus* that promote the degradation of FODMAPs (Laatikainen et al., 2016; Menezes et al., 2018).

2.9.1 Low FODMAP ingredients

Breads made from different types of ingredients and grains contain variable amounts of FODMAPs (Varney et al., 2017). Common Australian GF breads made from rice, corn, or tapioca tend to be low in FODMAPs, whereas breads made from rye (dark rye, rye sourdough) and wheat (wholegrain, wholemeal) tend to be high in FODMAPs (Biesiekierski et al., 2011). GF bread contains relatively lower amounts of fructans than wheat and rye breads commonly consumed in UK (Whelan et al., 2011). The total fructans in GF breads made from wheat starch are lower than GF breads made from potato, tapioca starch and maize flour as maize contains relatively higher amounts of fructans (Knudsen, 1997).

GF ingredients commonly used for GF bread-making such as rice, corn starch, potato starch, oat, quinoa, and buckwheat are generally low in FODMAPs, and only low to moderate amounts of GOS (raffinose and stachyose) are detected in these ingredients. The total fructans in these GF ingredients are lower than 0.1 g / 100 g (Ispiryan, Zannini & Arendt, 2020).

Addition of seeds and pulses in bread formulations can significantly enhance the nutritional values (protein content, vitamins and minerals) of bread products (Rahaie et al., 2014). However, seeds and flours from pulses such as lentil, soy, green pea, yellow pea, chickpea flour and fababean flour are generally considered as high FODMAP, in particular those containing relatively higher amounts of GOS (Ispiryan, Zannini & Arendt, 2020). Consumption of seeds and pulses might potentially cause flatulence or other GI symptoms of people with GI diseases

(Veenstra et al., 2010), therefore addition of these ingredients is not suggested for a low FODMAP bread formulation.

2.9.2 Yeast fermentation

Fructans as the major FODMAP in breads can be considerably degraded to glucose and fructose during dough fermentation by the enzyme invertase produced by the baker's yeast *S. cerevisiae* (Lammens et al., 2009). During dough fermentation, yeast utilises fructans as an energy source for metabolism. The yeast invertase is an extracellular β -fructofuranosidase that is capable of hydrolysing the β -(2-1) linkages in fructans. Verspreet et al. (2013) reported that about 80 % of the fructans within wheat whole meal were degraded during bread-making. Baker's yeast fermentation with prolonged proofing time (4.5 h) also effectively reduced nearly 90 % of initial dough levels of fructans, raffinose, and excess fructose in wheat and spelt breads (Ziegler et al., 2016).

When analysing the degradation of fructans with different degrees of polymerisation (DP) from wheat flour by yeast invertase, Nilsson et al. (1987) showed that during the first 10 minutes of mixing, different fructans showed different rates of degradation: trisaccharides 50 %, tetrasaccharides 40 %, pentasaccharides 20 %, and higher DP (higher molecular size, DP > 5) fructans 10 %. After 1 h of fermentation, all the lower DP (lower molecular size, DP \leq 5) fructans including trisaccharides, tetrasaccharides, and half of the pentasaccharides had been metabolised. However, only 30 % of the higher DP fructans were degraded in that period of time, thus demonstrating that the hydrolytic activity of invertase is dependent on the degree of polymerisation of fructans (Nilsson et al., 1987). It also showed that the optimum pH for hydrolysis of fructans by invertase is around 4.5 to 5.0 and for high DP fructans such as inulin is 6.0 (Nilsson et al., 1987). This explains why sourdough fermentation could result in greater hydrolysis of fructans due to their high metabolic activity under acidic conditions.

Different yeast strains have different abilities to degrade fructans. Struyf et al. (2017) suggested use of an alternative yeast specie *Kluyveromyces marxianus*, which is capable of degrading more than 90 % of wheat grain fructans within 2.5 h of dough fermentation. In contrast to the baker's yeast invertase, inulinase secreted by *K. marxianus* possesses a higher specificity for high DP fructans such as inulin. Since *K. marxianus* inulinase can easily access the fructans, it can be secreted into the dough, whereas invertase produced by *S. cerevisiae* is retained in the yeast cell wall. Thus, higher levels of fructans might be degraded by *K. marxianus* than baker's yeast *S. cerevisiae*. Combining these two yeast strains as a co-culture for dough leavening and using a higher dosage of yeast may achieve almost complete degradation of fructans.

2.9.3 Sourdough fermentation

The underlying mechanisms contributing to the sourdough culture, is a complex microbial ecosystem (dominated by heterofermentative LAB and yeasts) that can degrade FODMAPs during sourdough fermentation (Loponen & Gänzle, 2018). Hence sourdough fermentation produces breads with low FODMAP content to help IBS patients restrict their dietary intake of the poorly digestible oligosaccharides (Laatikainen et al., 2016; Menezes et al., 2018; Loponen & Gänzle, 2018).

During the dough-forming step, flour α -amylase converts starch and liberates maltodextrins, which are hydrolysed by flour β -amylase and gluco-amylase into maltose and glucose (Gänzle & Follador, 2012). Sucrose is metabolised rapidly by yeast invertase into glucose and fructose. Sucrose can also be converted to polymeric fructo-oligosaccharides (kestose, nystose) or glucans by enzyme activities of fructansucrases and glucansucrases, which are extracellular enzymes from heterofermentative LAB (Gänzle, 2014). Heterofermentative LAB utilise glucose released from sucrose as an energy source and convert fructose to polyols (mannitol) by mannitol-dehydrogenase (Gobbetti et al., 2005). Kestose and nystose from wheat or rye flour are degraded by invertase from yeast or fructosidases from heterofermentative LAB

(Gänzle, 2015). Flour raffinose is degraded by yeast invertase and also extracellular levansucrase from LAB into fructose or fructan, and further hydrolysed by intracellular α -galactosidase to sucrose and galactose (Teixeira et al., 2012). Fructans within the dough are degraded by invertase activity of yeast as discussed in previous Section 2.9.2 (Knez, Abbott & Stangoulis, 2014; Struyf et al., 2017).

2.9.4 Prolonged sourdough fermentation

Prolonged sourdough fermentation (not less than 4 h) and retard proofing (fermentation at refrigeration temperature) can be used to reduce the FODMAP content of breads (Ziegler et al., 2016). All fermentable carbohydrates can be rapidly depleted in the first hour of fermentation through a series of enzymatic and bacterial metabolism (Nilsson, Öste & Jägerstad, 1987). However, higher DP polymeric oligosaccharides such as fructans are degraded very slowly (Knez, Abbott & Stangoulis, 2014). Hence prolonged sourdough fermentation can achieve higher degradation of FODMAPs. Doughs fermented at 30 °C with the fermentation time extended to 4.5 h can effectively degrade around 90 % of the FODMAP content of wheat wholegrain bread and 77 % for spelt bread (Ziegler et al., 2016). An increase of fructose has been reported within the first hour of fermentation, which is the product of fructan degradation (Verspreet et al., 2013). The concentration of excess fructose within 1 h of fermentation far exceeds the safe threshold of 0.5 g / 100 g for IBS patients. However, after 4.5 h fermentation, only negligible amounts of excess fructose are retained, again proving the importance of fermentation time on reducing FODMAP content (Ziegler et al., 2016).

Retard proofing (or retarding) is a slow fermentation process that is accomplished by placing the bread dough into a retarder-proofer or refrigerator at a temperature of 0 - 5 °C (Iwashita, Shirai & Adachi, 2002). Retard proofing is often applied in artisan sourdough bread-making to develop a full characteristic flavour and hold more gas within the crumb structure (Rinsky & Rinsky, 2008). Prolonged fermentation time (normally 12-18 h) is required to leaven the dough

as the activity of yeast is reduced at low temperatures (Pagani, Bottega & Mariotti, 2013). Although retard proofing delays the process of fermentation, LAB would be still active and carrying out metabolic activities, but cooler fermentation temperatures lead to more acetic acid production, which could impact on the sensory quality of the final bread (Rayner, 2009).

2.9.5 Specific sourdough starter cultures

The extent of FODMAP degradation during sourdough fermentation is also affected by the choice of microorganisms used in the starter culture. Typical sourdough LAB such as *L. fermentum*, *L. plantarum* and *L. brevis* can metabolise fructans, FOS, and GOS (Kunová et al., 2011). Isolated *L. plantarum* and *L. curvatus* can metabolise the fructose and polyols generated from fructan degradation (Bartkiene et al., 2017).

Few strains of sourdough LAB, such as *L. amylovorus* and *L. crispatus* can convert fructans into fructose and sucrose, which are further metabolised by homofermentative LAB to form lactic acid, acetic acid, ethanol and CO₂ (Müller & Lier, 1994). *L. paracasei* has been reported to degrade fructans including long chain inulin by the extracellular β -fructosidase (Makras, Van Acker & De Vuyst, 2005). Several *Lactobacillus* spp., *L. fermentum*, *L. brevis* and *L. Buchner* produce α -galactosidase, which can convert indigestible GOS to digestible carbohydrates (Silvestroni et al., 2002). Teixeira et al. (2012) showed *L. reuteri* LTH5448 in sorghum sourdough added with faba bean flour completely degraded total GOS in GF bread dough after 2 h of fermentation. This was attributed to the levansucrase and α -galactosidase activities of *L. reuteri* and *L. fermentum*, the dominant LAB species isolated from sourdough breads, which can convert fructose to mannitol (De Vuyst & Vancanneyt, 2007; Vrancken et al., 2008).

A few studies have used specific sourdough LAB to reduce the indigestible carbohydrate content of sourdough. Rizzello et al. (2010) used *L. plantarum* LB1 and *L. rossiae* isolated from wheat germ as the starter culture for wheat germ sourdough fermentation. The fructose and

raffinose of the fermented sourdough decreased by 87 % and 45 %, respectively. Another study by Curiel et al. (2015) used *L. plantarum* C48 and *L. brevis* AM7 isolated from traditional Italian legumes as the starter culture to reduce raffinose by 64 % in 24 h fermentation. Therefore, development of low FODMAP breads can also be achieved by selection of suitable sourdough starter cultures that catalyse the degradation of FODMAPs.

2.10 Quantification of FODMAPs in Foods

2.10.1 Conventional and recent techniques

Conventional techniques used for the analysis of carbohydrates in foods include gas chromatography coupled with mass spectrometry (GC-MS), high-performance liquid chromatography equipped with refractive index detection or evaporative light scattering detection (HPLC-RI or HPLC-ELSD), and HPAEC-PAD (Churms, 1990; Molnár-Perl, 2000; Montero et al., 2004; BeMiller, 2010; Snyder, Kirkland & Dolan, 2010). However, these techniques all have disadvantages: GC-MS requires analytes to be derivatised prior to analysis (Ruiz-Matute et al., 2011); HPLC-RI lacks sensitivity and is not compatible with gradient elution (Magwaza & Opara, 2015), while HPLC-ELSD has low reproducibility and poor selectivity (Molnár-Perl, 2000), resulting in co-elution of carbohydrate sugars with similar configurations (e.g., glucose and sorbitol, raffinose and stachyose, or nystose and kestose) (Folkes & Jordan, 2006; Muir et al., 2009). HPAEC-PAD is a powerful technique for analysing mono-, di-, oligo-, and polysaccharides as well as sugar alcohols in foods, which has high resolution and enables direct analysis of samples without prior derivatisation (BeMiller, 2010; Cataldi, Campa & De Benedetto, 2000; Corradini, Cavazza & Bignardi, 2012). Recently, HPAEC-PAD has been successfully used to quantify the FODMAPs in cereals and cereal-based products, and therefore represents a promising approach for supporting the development of low FODMAP food products (Ispiryan et al., 2019; Ispiryan, Zannini & Arendt, 2020).

2.10.2 Separation mechanism

The separation mechanism of anion-exchange chromatography is based on the weak acidic nature of carbohydrates, which are either partially or completely ionised into anions under high alkaline conditions ($\text{pH} > 12$) depending on their $\text{p}K_a$ values (Cataldi, Campa & De Benedetto, 2000). HPAEC uses a strong and highly stable anion-exchange stationary phase that possesses positively charged functional groups which interact with the negative charges of the analytes in the mobile phase (Palmigiano et al., 2018). The separation is influenced by several factors, including the number of hydroxyl groups, the degree of polymerisation, and the position of the isomerism of the analytes (Corradini, Cavazza & Bignardi, 2012). In general, carbohydrates with lower $\text{p}K_a$ values have a stronger affinity for the stationary phase and will be retained on the column longer (Lee, 1990).

2.10.3 Pulsed amperometric detection

The principle of pulsed amperometric detection (PAD) measures changes in an electrical current generated by the oxidation of the eluted analytes at the working gold electrode (Brunner & Cui, 2005). PAD gives high sensitivity and specificity for direct quantification of carbohydrates without derivatisation and has low detection limits to the nanomolar level (Jahnel, Ilieva & Frimmel, 1998).

PAD of carbohydrates was previously based on three-potential waveforms (LaCourse & Johnson, 1993), and uses three different attempts of waveforms in each cycle: the first attempt oxidises the carbohydrates (detection of the current generated from carbohydrate oxidation); a second with more positive potential cleanses the gold electrode (removing the oxidation products from the surface of electrode); thirdly, a negative potential reduces the gold oxide back to gold (to prepare for the next detection cycle) (Rocklin, Clarke &

Weitzhandler, 1998; Corradini, Cavazza & Bignardi, 2012). The drawback of this triple-potential waveform is the formation of surface oxides (or an electrochemical erosion) on the gold electrode surface caused by the positive cleaning potentials, which results in decreased detector responses and loss of sensitivity over time (Rocklin, Clarke & Weitzhandler, 1998; Cataldi & Nardiello, 2003).

Therefore, a quadruple-potential waveform was introduced for amperometric detection of carbohydrates (Rocklin, Clarke & Weitzhandler, 1998; Rohrer, 2013). The waveform of the electrochemical detector is 0.10 V from 0 to 0.40 s, then - 2.0 V from 0.41 to 0.42 s, and ramps from - 2.0 V to 0.60 V during 0.42 to 0.43 s, followed by - 0.1 V from 0.44 to 0.50 s. This quadruple-potential waveform uses the negative potentials to cleanse the gold electrode, thereby eliminating the electrode recession and improves the long-term reproducibility (Cataldi, Campa & De Benedetto, 2000; Santamaría, Barambio & Arribas, 2015).

2.10.4 Stationary and mobile phase

The most common analytical columns specifically designed by Dionex for carbohydrate analyse by HPAEC-PAD and their applications are shown in Table 3 (Corradini, Cavazza & Bignardi, 2012). The anion-exchange (AEX) resins (stationary phase) mainly consist of ethylvinylbenzene-divinylbenzene cross-linked polymers coated with latex microbead polymer functionalised with quaternary ammonium ions (Dionex Corporation, 2004; Corradini, 2000). This packing material has high stability over a broad pH range (pH 0-14) and is capable of quickly separating carbohydrates using low concentrations of sodium hydroxide as the mobile phase (Liang et al., 2006).

Table 3 Most common columns used for carbohydrate HPAEC-PAC analysis*

Column	Description	Application
CarboPac MA1	7.5 µm diameter, macroporous, AEX	Reduced mono- and disaccharides, sugar alcohols
CarboPac PA1	10 µm diameter, nonporous, AEX	Mono-, di-, and oligosaccharides
CarboPac PA10	10 µm diameter, nonporous, AEX	Mono- and disaccharides
CarboPac PA20	6.5 µm diameter, nonporous, AEX	Mono-, di-, and short oligosaccharides, sugar alcohols
CarboPac PA100	8.5 µm diameter, nonporous, AEX	Oligosaccharides and polysaccharides
CarboPac PA200	5.5 µm diameter, nonporous, AEX	Oligosaccharides
CarboPac PS10	6.0 µm diameter, nonporous, AEX	Mono- and disaccharides

*Reviewed by Corradini (2000) according to the technical note from Dionex. AEX = anion-exchange.

Aqueous solution of sodium hydroxide (NaOH) or aqueous solution of NaOH and sodium acetate (NaOAc) are the most common mobile phases for analysis of carbohydrates by HPAEC-PAD, since strong alkaline solutions allow analytes to be deprotonated (Cataldi, Campa & De Benedetto, 2000; Pico, Bernal & Gomez, 2015). The concentration of hydroxide ions (OH^-) in the mobile phase strongly influence the selective and retention time of the analysis (Rohrer, 2012). By increasing the concentration of OH^- , the dissociation degree of the carbohydrates or the eluting power of the eluent increases, thus the retention of the analytes on the anion-exchange stationary phase is enhanced (Landberg, Lundblad & Pålsson, 1998; Weiss, 2016). Carbohydrates such as oligosaccharides and polysaccharides with higher affinity toward the stationary phase can be separated by addition of NaOAc in the mobile phase, as the acetate ion (Ac^-) has higher elution strength than OH^- (Weiss, 2016). The use of NaOH and NaOAc mixture as gradient elution can also significantly reduce the retention time for separation of oligosaccharides (Anders et al., 2015).

CHAPTER 3 MATERIALS AND METHODS

3.1 Experimental Design

This study aimed to quantify FODMAPs in seven commercial GF breads (three conventional GF breads and four GF sourdough breads) produced by a local company in NZ and reduce the levels of FODMAPs in existing GF sourdough bread containing the highest levels of FODMAPs by reformulating and using retard proofing (fermentation at refrigeration temperature). The effects of sourdough fermentation on the FODMAP degradation and the characteristics of low FODMAP GF sourdough breads were investigated using five integrated phases (Figure 6). The first phase involved the quantification of FODMAPs of seven commercial GF breads produced by a local company in NZ. The second phase aimed to reduce the levels of FODMAPs in the GF sourdough bread containing the highest levels of FODMAPs (GF sweet potato sourdough bread) by reformulation (using low FODMAP ingredients, reducing high FODMAP constituents, increasing the amount of sourdough starter addition) and using retard proofing (fermentation at refrigeration temperature). The third phase investigated the effects of sourdough fermentation on the microbiological and physico-chemical characteristics, and the FODMAPs during propagation of GF sourdough starter. The fourth phase investigated the effects of different formulations and fermentation processes on the microbiological and physico-chemical characteristics, and the FODMAPs of bread dough samples (before and after proofing) and bread samples of GF sweet potato sourdough breads. In the final phase, the effects of different formulations and fermentation processes on the baking characteristics and consumer acceptability of GF sweet potato sourdough breads with reduced FODMAP levels were investigated.

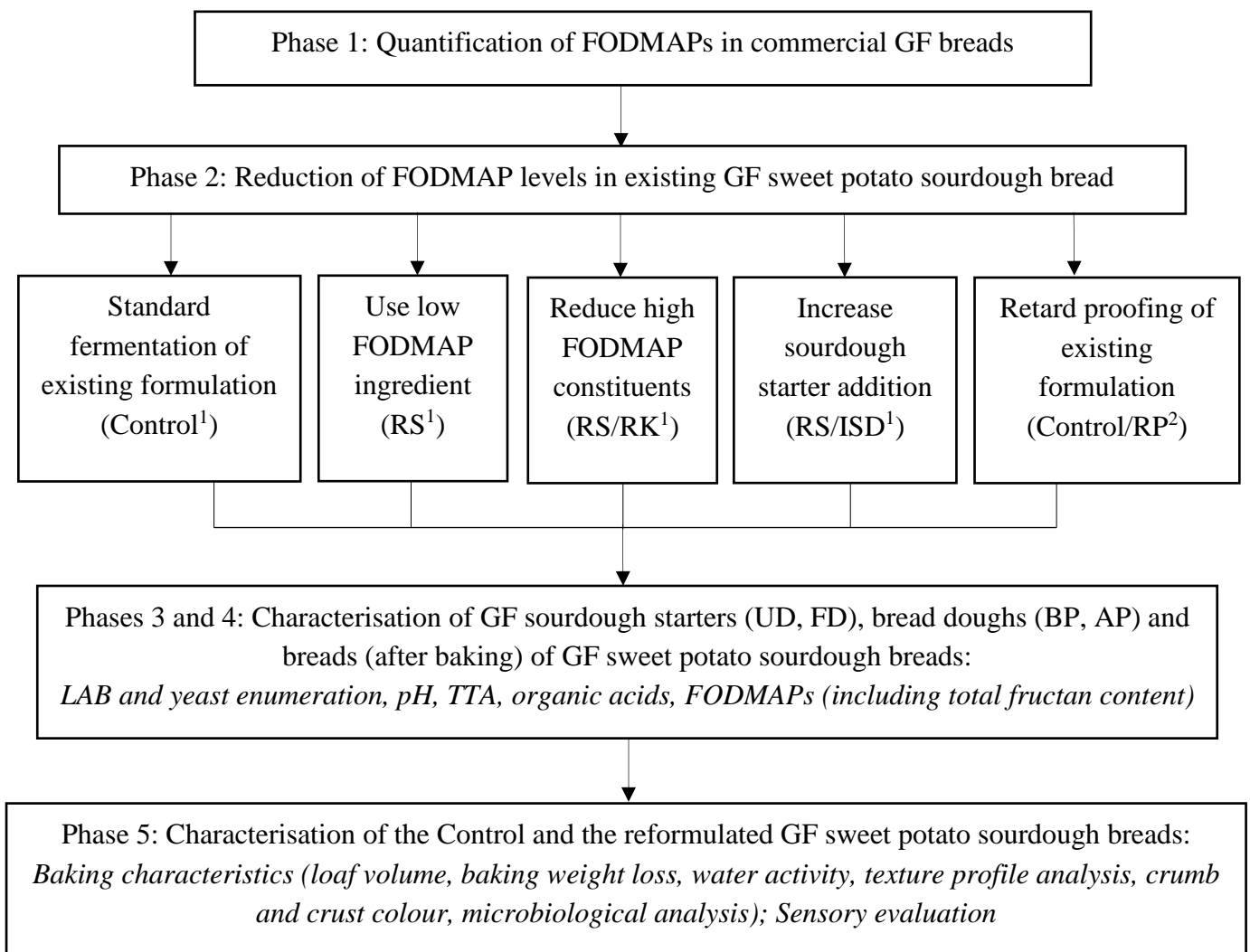


Figure 6 The five experimental phases of this study

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; UD = unfermented sourdough starter, sourdough starter before propagation; FD = fermented sourdough starter, sourdough starter after propagation; BP = bread dough before proofing; AP = bread dough after proofing; TTA = total titratable acidity.

3.1.1 Commercial GF breads used for FODMAP analysis

Seven commercially manufactured NZ GF breads (three conventional GF breads and four GF sourdough breads) used for FODMAP analysis were chosen by the local company based on the popularity of their products. The description of the conventional GF breads and GF sourdough breads used for FODMAP analysis are shown in Table 4.

Table 4 Description of commercial GF breads used for FODMAP analysis

Sample	Product	Description
GF1	Gluten Freedom White 495 g	Gluten free bread made from tapioca/maize starch, rice/sorghum/coconut flours.
GF2	GF Paleo Super Seeded 550 g	Gluten free bread made from seeds 27.5% (sunflower, sesame, pumpkin, linseed, and poppy), tapioca starch, almond meal, coconut flour.
GF3	GF Paleo Almond & Linseed 550 g	Gluten free bread made from tapioca starch, almond meal, linseed, kumara powder, coconut flour.
GFSD1	GF Sweet Potato Sourdough Bread 300 g	Gluten free organic sourdough bread bun made from brown rice flour, tapioca/corn starch, kumara (sweet potato) powder, polenta.
GFSD2	GF Broken Black Rice & Polenta Sourdough Bread 550 g	Gluten free organic sourdough bread made from brown rice/wholegrain corn/red sorghum flours, tapioca/corn starch, polenta, kumara powder, broken black rice, buckwheat flakes, linseeds.
GFSD3	GF Organic Sourdough Six Seed 600 g	Gluten free organic sourdough bread made from brown rice/white rice/maize flours, tapioca starch, seeds 11% (flax, quinoa, sesame, poppy, sunflower, and pumpkin).
GFSDNY	GF Organic Sourdough Brown No Added Yeast 600 g	Gluten free organic sourdough bread made from brown rice/white rice/maize/besan flours, tapioca starch, with no yeast added.

GF1 = gluten free bread sample 1; GF2 = gluten free bread sample 2; GF3 = gluten free bread sample 3; GFSD1 = gluten free sourdough bread sample 1; GFSD2 = gluten free sourdough bread sample 2; GFSD3 = gluten free sourdough bread sample 3; GFSDNY = gluten free sourdough bread without added yeast.

3.1.2 Reformulation of the existing GF sweet potato sourdough bread

Results from Phase 1 showed that the GF sweet potato sourdough bread (GFSD1) contained the highest levels of FODMAPs of the 7 breads analysed. Therefore, the bread formulation of GFSD1 was selected for development of low FODMAP GF sourdough bread. To develop low FODMAP bread, all the ingredients used in the formulation should be low in FODMAPs. Three GF sweet potato sourdough breads (RS, RS/RK and RS/ISD) were reformulated based on the existing bread formulation by replacing coconut sugar (high FODMAP) with rice syrup (low FODMAP) (Monash University, 2019). The percentage of kumara flour in the RS/RK formulation was decreased from 2.81 % in the existing formulation to 1.50 % as kumara flour is potentially high in mannitol, a FODMAP sugar (Monash University, 2019). The RS/ISD GF sweet potato sourdough bread was reformulated with higher levels of sourdough starter (35.00 %) compared with the existing formulation (24.31 %). The basic formulations for the existing GF sweet potato sourdough bread (Control) and the reformulated GF sweet potato sourdough breads are shown in Table 5.

Table 5 Basic formulations of the Control and the reformulated GF sweet potato sourdough breads

Group of Ingredients	Ingredients	% by Weight of Ingredients in Formulations			
		Control	RS	RS/RK	RS/ISD
Composite Flour	Tapioca starch	17.78	17.78	18.66	14.88
	Hi-Maize starch	4.44	4.44	4.56	3.72
	Corn starch	6.89	6.89	7.20	5.77
	Kumara flour	2.81	2.81	1.50	2.35
	Fibre	0.88	0.88	0.88	0.74
Other Ingredients	Sourdough	24.31	24.31	24.31	35.00
	Water	33.10	33.10	33.10	27.76
	Stabiliser	0.41	0.41	0.41	0.41
	Emulsifier	0.07	0.07	0.07	0.07
	Guar gum	0.26	0.26	0.26	0.26
	Coconut oil	3.66	3.66	3.66	3.66
	Coconut sugar	3.74	-	-	-
	Rice syrup	-	3.74	3.74	3.74
	Salt	0.53	0.53	0.53	0.53
Yeast	1.11	1.11	1.11	1.11	
Total		100.00	100.00	100.00	100.00

All the ingredients were supplied by a local company in NZ. Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter.

3.1.3 Production of GF sweet potato sourdough bread by retard proofing

The Control/RP GF sweet potato sourdough bread was produced with the same formulation as the Control GF sweet potato sourdough bread but using retard proofing in chiller at 8 °C/87 % RH with a thin polyethylene liner (Figure 7) until the volume of the bread dough had doubled in size and reached the optimised conditions. Comparison of the proofing conditions of the Control and the Control/RP GF sweet potato sourdough bread are given in Table 6.



Figure 7 Control/RP bread doughs during retard proofing in a chiller at 8 °C/87 % RH
(Image was captured by iPhone 11 Pro, Apple Inc., USA)

Table 6 Comparison of the proofing conditions of the Control and the Control/RP GF sweet potato sourdough breads

Proofing Conditions	Control	Control/RP
	Standard fermentation for 1 h at 37 °C/87 % RH in the prover	Retard proofing for 12 h at 8 °C/87 % RH in the chiller

Control = GF sweet potato sourdough bread with coconut sugar; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing.

3.1.4 Summary of the testing parameters in this study

A summary of the parameters that were determined in this study for the GF sourdough starter (SD), bread dough (BD) and bread samples of the Control and the reformulated GF sweet potato sourdough breads is listed in Table 7.

Table 7 Parameters that were determined for the GF sourdough starter samples during propagation, the bread dough samples (before and after proofing), and the bread samples (after baking) of the GF sweet potato sourdough breads

Samples	Parameters
SD (UD 0 h, FD 24 h, FD 48 h, FD 72 h)	LAB and yeast counts; pH and TTA; Organic acids (lactic and acetic acid); FODMAPs (including total fructan content)
BD (BP, AP)	LAB and yeast counts; pH and TTA; Organic acids (lactic and acetic acid); FODMAPs (including total fructan content)
Breads	pH and TTA; Organic acids (lactic and acetic acid); FODMAPs (including total fructan content); Baking characteristics (loaf volume, baking weight loss, water activity, texture profile analysis, crumb and crust colour, microbiological analysis); Sensory evaluation

SD = GF sourdough starter; UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation. BD = bread dough; BP = bread dough before proofing; AP = bread dough after proofing.

3.2 Phase 1: Quantification of FODMAPs in Commercial GF Breads

3.2.1 Samples, reagents, and standards

All reference standards for sugars used for analysing FODMAPs were of analytical grade or higher (>98% purity). Glucose (D-(+)-Glucose), fructose (D-(-)-Fructose), sorbitol (D-Sorbitol), mannitol (D-Mannitol), raffinose (D-(+)-Raffinose pentahydrate), stachyose (Stachyose hydrate from *Stachys Tuberifera*), kestose (1-Kestose), nystose (1-Nystose), and rhamnose (L-Rhamnose) were purchased from Sigma-Aldrich (Darmstadt, Germany). Potassium hexacyanoferrate (II) (Carrez I, $K_4[Fe(CN)_6] \cdot 3 H_2O$) and zinc sulphate heptahydrate (Carrez II, $ZnSO_4 \cdot 7 H_2O$) were obtained from Fisher Scientific (Loughborough, UK). Milli-Q high-grade water was obtained using a Milli-Q Ultrapure Water Purification System (Millipore, Milford, MA). HPLC-grade acetonitrile (CH_3CN), methanol (MeOH), glacial acetic acid (AcOH), 50% (w/w) sodium hydroxide (NaOH), and sodium acetate (NaOAc) were purchased from Fisher Scientific (Loughborough, UK) (Ispiryan et al., 2019).

3.2.2 Preparation of bread samples for FODMAP quantitation

For quantification of FODMAPs, 1000 g of each bread sample used were supplied by a local GF bakery company. Each bread sample was blended in a food processor (Breville, Sydney, AU) into homogeneous mixtures and approximately 100 g of each bread sample was stored at -20 °C overnight (Walk-in Freezer, North Shore Refrigeration and Air Conditioning Ltd, NZ) and then lyophilised using a Labconco FreeZone 6 Freeze Dry System (Labconco, Kansas, MO) to constant weight. The lyophilised samples were ground to a powder with a kitchen grinder (Breville, Sydney, AU) and sealed in stomacher bags (Global Science, NZ) prior to FODMAP analysis.

3.2.3 Extraction of FODMAPs from the bread samples

The extraction method used for FODMAPs from the bread samples was based on Ispiryan et al. (2019). Aliquots of 0.4 g of freeze-dried bread samples were weighed into 50 mL plastic centrifuge tubes, mixed thoroughly with 1 mL of MeOH and left for 5 min to inactivate the native enzymes (such as α -amylases) in the samples. Before extraction, 100 μ L of rhamnose (9 mg/mL) internal standard was added into each sample solution. Twenty mL of 80 °C distilled water was added and the tubes were mixed thoroughly for 30 s using a vortex mixer (VELP Scientifica, Italy), followed by ultrasonic extraction (Bandelin Sonorex Super RK510, Germany) for 10 min, then cooled to room temperature (20 °C) and centrifuged at $1520 \times g$ (Heraeus Multifuge 1R, Thermo Fisher Scientific Inc., Germany) for 5 min at 20 °C. After centrifugation, the supernatants were transferred into 100 mL volumetric flasks and the sediments were extracted again with 20 mL of hot (80 °C) distilled water. The supernatants were combined in the 100 mL volumetric flask, and 200 μ L of Carrez-I solution (15 g/100 mL) and 200 μ L of Carrez-II solution (23 g/100 mL) were added to precipitate the proteins and then the volume was adjusted to 100 mL with distilled water. The solutions were centrifuged at $3000 \times g$ for 10 min at 20 °C and supernatants of the extracts were filtered through 0.22 μ m syringe driven filter units (Millipore Corporation, USA) and transferred into 2 mL HPLC vials prior to immediate analysis. If immediate analysis could not be carried out, the filtered samples were stored at -20 °C and reheated to 80 °C and cooled to room temperature (20 °C) before analysis. Sample extractions were done in duplicate.

3.2.4 Quantification of FODMAPs in GF bread samples by HPAEC-PAD

HPAEC-PAD was used to quantify the FODMAPs in the bread samples by the method of Ispiryan et al. (2019) with some modifications. Analysis of FODMAPs was performed using a Dionex ICS-5000 system (Dionex, Sunnyvale, USA) consisting of an auto-sampler AS-AP, a gradient pump DP-5000, and an electrochemical detector (pulsed amperometric) ED-5000. The

pulsed amperometric detection was achieved by a gold working electrode using an Ag/AgCl reference electrode, with a data collection rate of 20 Hz. The pulsed potentials were set to E1 = + 0.10 V (from 0 to 0.40 s), E2 = - 2.0 V (from 0.41 to 0.42 s), E3 = + 0.60 V (from 0.42 to 0.43 s), and E4 = - 0.10 V (from 0.44 to 0.50 s).

The separation of FODMAP sugars was achieved using a Dionex CarboPac PA20 column (3 mm × 150 mm) in combination with a Dionex CarboPac PA20 guard column (3 mm × 50 mm) (Dionex, Sunnyvale, USA) at 30 °C with a flow rate of 0.45 mL/min. The CarboPac PA20 column has good separation ability of monosaccharides and disaccharides (Kun-Tian et al., 2008; Arnous & Meyer, 2008). A few HPAEC-PAD analyses have also proven that with gradient elution, this column could simultaneously separate sugar alcohols and short oligosaccharides in foods (Palma et al., 2014; Dionex Corporation, 2011; Zhu, Ning & Du, 2017). The injection volume was 25 µL and sample analysis was performed in duplicate (n = 2). The eluents were purified water (solution A), 200 mM NaOH (solution B), and 400 mM NaOAc (solution C).

The gradient programme for the separation of the carbohydrates by HPAEC-PAD on the CarboPac PA20 column is shown in Table 8. Carbohydrates were quantified using five-point calibration curves obtained from mixed standard working solutions (prepared daily and stored at 4 °C) with concentrations ranging from 0.20 - 2.00 mg/L. Dionex Chromeleon 7.2 software was used for data acquisition and processing. The precision of the method was checked by repeated injections of each sugar standard (n = 6). The relative standard deviation (% RSD) of the signal response of six standard injections was calculated (with acceptable precision % RSD < 5 %). The analytical results are expressed as grams per 100 g weight (as consumed) of each sample (n = 2).

Table 8 Gradient programme for carbohydrate separation by HPAEC-PAD on the CarboPac PA20 column

Time (min)	Eluent		
	A (%)	B (%)	C (%)
0	90	10	0
20.0	90	10	0
25.0	70	30	0
30.0	50	50	0
45.0	25	50	25
60.0	0	50	50
60.1	0	100	0
65.0	0	100	0
65.1	90	10	0
80.0	90	10	0

A = H₂O; B = 200 mM NaOH; C = 400 mM NaOAc.

3.2.5 Measurement of total fructans in GF bread samples by enzymatic assay

The total fructans in the bread samples were determined using the Megazyme Fructan HK Assay Kit (Megazyme International Ireland Ltd., Wicklow, Ireland) according to the AOAC method 999.03 and AACC method 32.32.01 (McCleary, Murphy & Mugford, 2000). The principles of this enzymatic assay include extraction of sugars, enzymatic hydrolysis of sucrose and maltosaccharides with low degree of polymerisation, followed by two parallel assays of the sample, one with no treatment, the another treated with fructanase to completely hydrolyse the fructan to free D-fructose and D-glucose. The D-fructose and D-glucose were analysed using a colourimetric reaction based on the ability of hexokinase (HK) and phosphoglucose isomerase (PGI) to phosphorylate D-fructose and D-glucose to glucose 6-phosphate (G-6-P). With the addition of glucose 6-phosphate dehydrogenase (G-6-PDH) and an NADP⁺/ATP mixture, G-6-P is oxidised to gluconate-6-phosphate, yielding NADPH and H⁺ ions. The amount of NADPH produced from the reaction is stoichiometric with the amount of D-fructose and D-glucose present in the solution and can be measured spectrophotometrically at an absorbance of 340 nm. Principles of this assay are summarised in Figure 8.

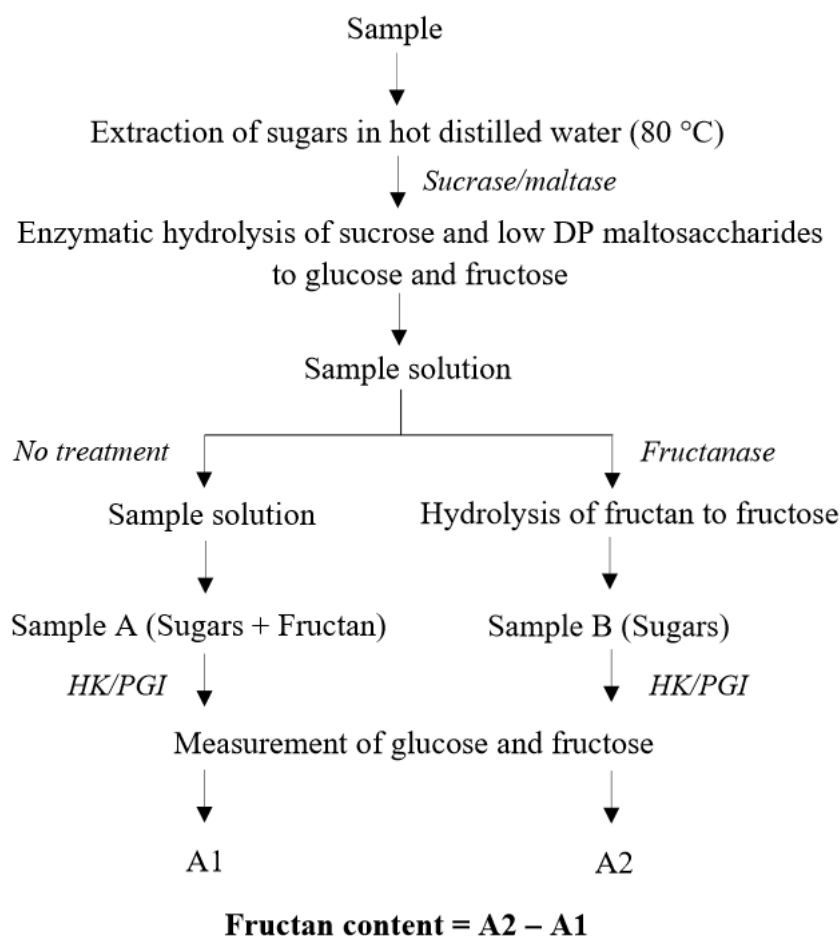


Figure 8 The principles of Megazyme K-FRUCHK Assay Kit (Muir et al., 2007)

DP = degree of polymerisation; *HK/PGI* = hexokinase/phosphoglucose isomerase; A1 = absorbance of sample A (sugars + fructan); A2 = absorbance of sample B (sugars).

Approximately 1g of the previously freeze-dried and ground sample was weighed into a dry 100-mL Pyrex beaker and 40 mL hot (80 °C) distilled water was added. The mixture was stirred and heated at 80 °C on a hot plate magnetic stirrer for 15 min to completely mix the sample. The mixture was cooled to room temperature (20 °C) and the solution was quantitatively transferred into a 50-mL volumetric flask and the volume adjusted with distilled water. The mixture was mixed thoroughly by inversion and an aliquot of each sample was filtered through 9 cm Whatman No. 1 filter paper (Whatman PLC, UK) into a test tube for analysis. Of the solutions, 0.2 mL was accurately dispensed into glass test tubes (16 × 100 mm) and incubated

with 0.2 mL sucrase and maltase mixture solutions in a 40 °C water bath (Grant, Global Science, NZ) for 30 min. This was followed by the addition of 0.5 mL 100 mM sodium acetate buffer (pH 4.5) and vigorous mixing using a vortex mixer. From this solution, 0.2 mL was transferred into two glass test tubes and then 0.1 mL of the fructanase solution was added to the first test tube (Sample A = Sample Sugars), and 0.1 mL of 100 mM NaOAc solution was added to the second test tube (Sample B = Sample Sugars + Fructan). All the test tubes were covered with Parafilm (Heathrow Scientific, Vernon Hills, IL, USA), mixed thoroughly and incubated in a 40 °C water bath (Grant, Global Science, NZ) for 30 min to allow complete hydrolysis of the fructan in Sample A to free D-fructose and D-glucose. The solutions were then carefully transferred into 3-mL plastic spectrophotometer cuvettes (Thermo Fisher, NZ) and the fructan measurements were conducted using an UV-Visible spectrophotometer (UV-1601, Shimadzu, Japan) at 340 nm against a distilled water blank. Distilled water (2 mL), 0.2 mL of a buffer (pH 7.6) supplied with the kit, and 0.1 mL of NADP⁺/ATP mixture solution were added into the cuvettes. The cuvettes were covered with Parafilm then mixed thoroughly by gentle swirling. The absorbances of both cuvettes were recorded after approximately 3 min (A1) followed by addition of 0.02 mL of HK/PGI/G-6-PDH suspension into the cuvettes. After approximately 10-12 min or after the reaction had completed (determined as when the reading had remained constant for 5 min), then the absorbances of both cuvettes were recorded (A2).

Total fructan content of the bread samples were calculated using the Megazyme Mega-Calc™ K-FRUCHK_CALC Excel calculation program provided by the manufacturer based on Equations 1 to 5. Each sample was analysed in duplicate (n = 2) and the total fructans were converted to g/100g of fresh weight bread sample from the concentration (%) of dry weight obtained through lyophilisation.

Determination of the absorbance difference for both samples:

$$\Delta A \text{ Sugars} = A2 - A1 \text{ (Sample Sugars)} \dots \dots \dots \text{Equation 1,}$$

$$\Delta A \text{ Sugars} + \text{Fructan} = A2 - A1 \text{ (Sample Sugars} + \text{Fructan)} \dots \dots \text{Equation 2.}$$

Where ΔA is the difference of the absorbance of both samples.

Determination of the concentration of “Sugars” and “Sugars + Fructan”:

$$C (\text{Sugars}) \text{ g/L} = \Delta A \text{ Sugars} \times 1.6858 \dots \dots \dots \text{Equation 3,}$$

$$C (\text{Sugars} + \text{Fructan}) \text{ g/L} = \Delta A \text{ Sugars} + \text{Fructan} \times 1.6858 \dots \dots \dots \text{Equation 4.}$$

Where $C (\text{Sugars})$ is the concentration of the sugars in sample A (g/L), $C (\text{Sugars} + \text{Fructan})$ is the concentration of the sugars and fructan in sample B (g/L), 1.6858 is the coefficient provided by the K-FRUCHK_CALC Excel calculation program with volumetric and spectrophotometry conversion based on the assay procedure.

Determination of the concentration of “Fructan”:

$$C (\text{Fructan}) \text{ g/L} = C(\text{Sugars} + \text{Fructan}) - C (\text{Sugars}) \times 162/180 \dots \dots \text{Equation 5.}$$

Where $C (\text{Fructan})$ is the concentration of fructan (g/L), 162/180 is the conversion factor determined by free D-fructose and D-glucose to anhydrofructose and anhydroglucose as occurred in fructan.

3.3 Phase 2: Reduction of FODMAP Levels in Existing GF Sweet Potato Sourdough Bread

3.3.1 Overview of GF sweet potato sourdough bread production

The Control and the reformulated GF sweet potato sourdough breads were prepared following the procedure shown in Figure 9. The sampling plan for the unfermented and fermented GF sourdough starters, bread doughs before and after proofing, and baked breads after baking are also included in the production procedure.

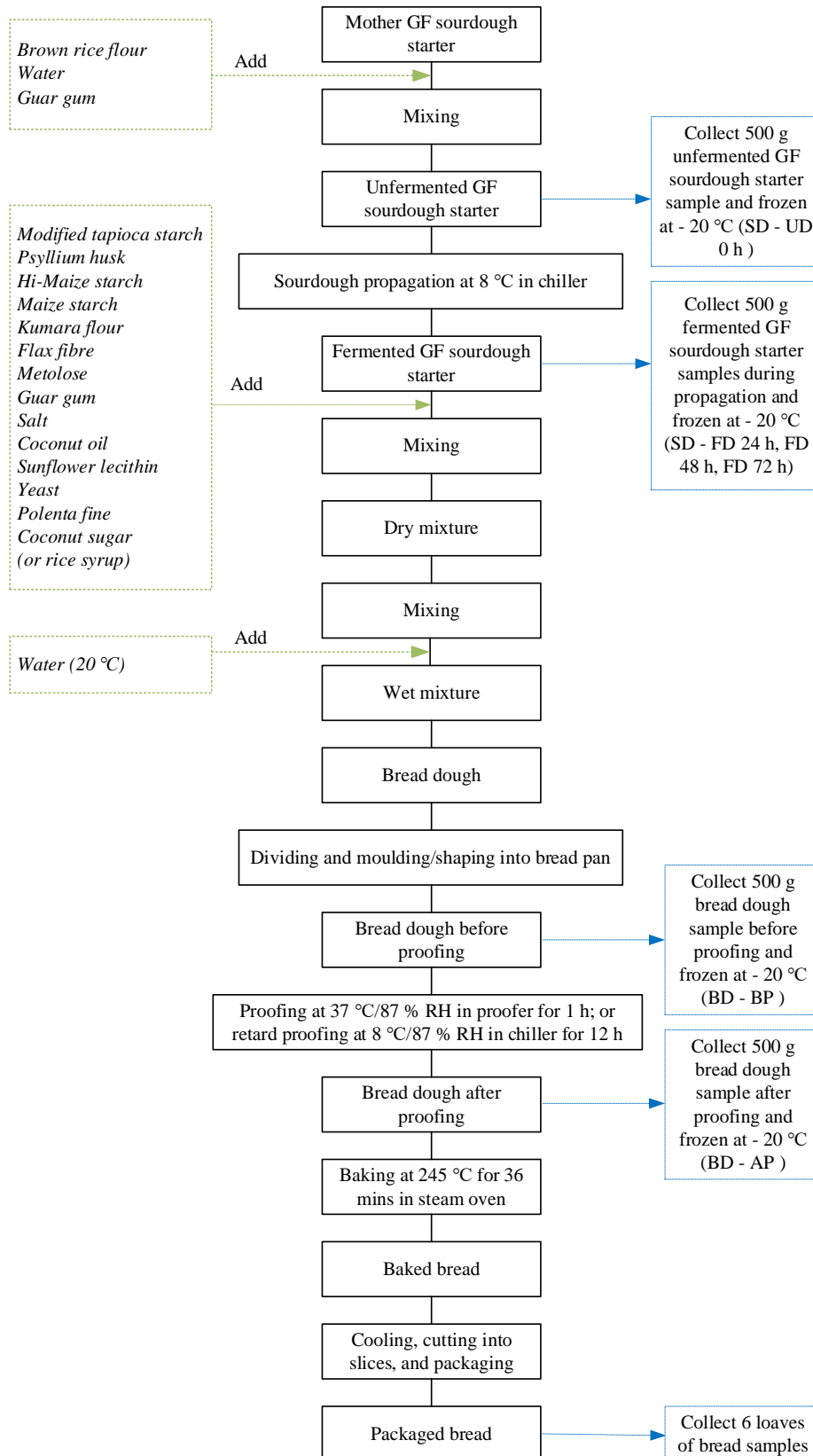


Figure 9 Production procedure of GF sweet potato sourdough bread

SD = GF sourdough starter; UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation. BD = bread dough; BP = bread dough before proofing; AP = bread dough after proofing; RH = relative humidity.

3.3.2 Propagation of the GF sourdough starter

GF sourdough starter for production of the Control and the reformulated GF sweet potato sourdough breads (RS, RS/RK, RS/ISD, Control/RP) were obtained from a commercial bakery company in Auckland using the existing sourdough process. Sourdough starters were prepared by mixing 1 kg of mother sourdough starter with 1 kg of brown rice flour, 1 kg of water, and 20 g of guar gum. The unfermented GF sourdough starters were stored in a chiller (8 °C/87 % RH) for 2 - 3 days before being used for production of GF sourdough bread. In this study, GF sourdough starter propagated after 48 h was used for producing the GF sweet potato sourdough breads. GF sourdough starter from the same batch used for bread production was stored in the chiller for a further 24 h fermentation (giving a total of 72 h propagation) and used for analysis of the GF sourdough starter.

3.3.3 Bread production

All GF sweet potato sourdough breads used in this study were produced at a commercial bakery company in Auckland following the basic formulations for the Control and the reformulated GF sweet potato sourdough breads listed in Table 5. Six loaves were produced for each formulation by mixing brown rice flour sourdough starter with other ingredients (5 kg of wet mixture) in a dough mixer (Commercial 20L Planetary Dough Mixer, Cater Master, South Africa) to form the bread dough. The dough was then divided into pieces of 620 g and shaped into bread pans, then transferred to a dough proofer at 37 °C/87 % RH for 1 h (Control, RS, RS/RK, and RS/ISD) or retard proofing at 8 °C/87 % RH in the chiller until the volume of the bread doughs had doubled in size and reached the optimised conditions for baking (Control/RP). After proofing, the bread dough was baked in a steam oven (Revent Oven, Revent International AB, Sweden) at 245 °C for 36 min then removed from the oven and placed on a bench for 10 min. The baked breads were transferred onto bread shelves for cooling using a cooling fan system (AIF020 Industrial Stand Fan, Arlec Australia Pty Ltd, Australia) until the internal bread

temperature had cooled to room temperature (20 °C). After cooling, loaves were mechanically sliced (Mono Bread Slicer, Mono Equipment, UK) into 12.5 mm thickness then packaged (Multivac thermoforming packaging machine, Multivac Group, Germany) in modified atmosphere packaging (20 % CO₂/ 80 % N₂).

3.3.4 Sampling

Approximately 500 g of GF sourdough starter before (UD 0 h) and after fermentation (FD 24 h, FD 48 h and FD 72 h); 500 g of bread doughs for the Control and the reformulated GF sweet potato sourdough breads before proofing (BP) and after proofing (AP) were transferred into individual sterile stomacher bags (Global Science, NZ). The GF sourdough starter and bread dough samples were frozen at -20 °C before being transported to Massey University for physico-chemical and microbiological analysis. All the Control and the reformulated GF sweet potato sourdough bread samples (after baking) produced at the commercial bakery company were packed into a chilly bin with ice packs (~ 4 °C) then transported to Massey University. The bread samples were stored at room temperature prior to analyses.

3.4 Phases 3 and 4: Characterisation of GF Sourdough During Propagation, Bread Dough and Bread Samples of the Control and the Reformulated GF Sweet Potato Sourdough Breads

3.4.1 Enumeration of LAB and yeast

Ten grams of GF sourdough starter (UD, FD), and bread dough (BP, AP) samples of the Control and the reformulated GF sweet potato sourdough breads were diluted with 90 ml of peptone solution (0.1% w/v) and homogenised using a 400 mL Masticator paddle blender (IUL Instruments, Barcelona, Spain) for 2 min. The homogenates from the samples were subjected to 10-fold serial dilutions (10⁻⁴ to 10⁻⁷). One milliliter aliquot from each diluted sample was plated onto MRS (de Man, Rogosa and Sharpe) agar (Merck, Darmstadt, Germany) for

enumeration of LAB, and YGC (Yeast Extract Glucose Chloramphenicol) agar (Merck, Darmstadt, Germany) for enumeration of yeast. The MRS agar plates were incubated anaerobically at 37 °C for 48 h, and the YGC plates were incubated aerobically at 25 °C for 120 h (Lhomme et al., 2015; Menezes et al., 2019). All the samples were analysed in duplicate (n = 2). Developed colonies of LAB and yeast were counted using a colony counter (Bibby Scientific SC6, UK) and the results were expressed as log CFU g⁻¹.

3.4.2 Measurement of pH

The pH of GF sourdough starter (UD, FD), bread dough (BP, AP) and bread (after baking) samples of the Control and the reformulated GF sweet potato sourdough breads were measured in triplicate (n = 3) using a pH meter (HI2221, Hanna Instruments, UK) equipped with a glass electrode according to the AACC International Method 02-52.01 (AACC, 2010a). The pH meter was calibrated prior to the measurements using pH 4.0, 7.0, and 10.0 standard buffer solutions (LabServ, Thermo Fisher, NZ). Ten grams of test sample was weighed into a beaker containing 90 mL of distilled water and vigorously mixed for 30 min using a magnetic stirrer and the suspension was allowed to settle for 10 min. The supernatant from the suspension was then decanted into another beaker and the pH was immediately measured. The glass electrode probe was rinsed with distilled water between measurements.

3.4.3 Determination of total titratable acidity (TTA)

Sodium hydroxide (NaOH) solution (0.1 mol/L) was standardised according to the AOAC Official Method 936.16 (AOAC, 1990). To standardise the NaOH solution, 0.15-0.20 g of dried potassium hydrogen phthalate (KHP) (Univar, AjaxFinechem Pty Ltd, NZ) was weighed into a clean Erlenmeyer flask on an analytical balance (ML204/01, Mettler Toledo, Switzerland) and dissolved completely in 50 mL distilled water. About 0.5 mL of 1% phenolphthalein solution was added into the KHP solution and the solution was thoroughly mixed by swirling. The 0.1 mol/L NaOH solution was titrated against the KHP solution until the first persistent

pink colour was observed (pH 8.5) and the volume of NaOH (mL) used in the titration was recorded. The titration was repeated until concordant results were obtained. The concentration of NaOH solution used for sample titration was calculated using Equation 6:

$$M \text{ NaOH (mol/L)} = \frac{m \text{ KHP (g)}}{MW_{\text{KHP}} (204.23 \text{ g/mol}) \times V_{\text{NaOH}} (\text{mL})}$$

.....Equation 6.

Where M NaOH is the molarity of NaOH (mol/L), m KHP is the mass of KHP (g), MW_{KHP} is the molecular weight of KHP = 204.23 (g/mol), V NaOH is the volume (L) used in the titration.

For the determination of TTA, the supernatants of GF sourdough starter (UD, FD), bread dough (BP, AP) and bread (after baking) sample suspensions (Section 3.5.2) were decanted into clean Erlenmeyer flasks. Then 0.5 mL of 1% phenolphthalein solution was added to the supernatant and mixed thoroughly by swirling. Standardised 0.1 mol/L NaOH was used to titrate the supernatant of the test samples until the first persistent light pink colour (pH 8.5). The TTA values were expressed as the amount (mL) of NaOH 0.1 mol/L used to neutralise the supernatant, and the experiment was done in triplicate for each sample (n = 3).

3.4.4 Analysis of organic acids in GF sourdough starter, bread dough, and bread samples by HPLC

3.4.4.1 Extraction of organic acids from the GF sourdough starter, bread dough, and bread samples

Samples of GF sourdough starter, bread dough, and bread for HPLC analysis were prepared according to the method described by Lefebvre et al. (2002). Ten grams of test sample were placed into a beaker containing 60 mL of distilled water and vigorously stirred for 30 min, using a hot-plate magnetic stirrer (RT-10 power, IKA, Staufen, Germany). The mixture was then transferred into a 100-mL volumetric flask and made up to volume with distilled water.

The sample was centrifuged at $4000 \times g$ (Heraeus Multifuge 1R, Thermo Fisher Scientific Inc., Germany) for 15 min, at 15 °C. The supernatant was filtered through a 0.22 μm syringe driven filter unit (Millipore Corporation, USA). Ten-milliliter aliquots of the filtrate were mixed with 60 mL distilled water and clarified with 10 mL Carrez solution [5 mL Carrez-I solution containing 0.085 mol/L potassium hexacyanoferrate (II) and 5 mL Carrez-II solution containing 0.25 mol/L zinc sulphate heptahydrate] (Thermo Fisher, NZ). The supernatant was neutralised to $\text{pH } 8.0 \pm 0.5$ with 0.1 M NaOH, the volume adjusted to 100 mL with distilled water, and filtered using a 0.22 μm syringe driven filter unit into 2.0 mL HPLC vials (Shimadzu Corporation, Japan) followed by immediate HPLC analysis.

3.4.4.2 Analysis of organic acids in GF sourdough starter, bread dough and bread samples

The HPLC analysis of organic acids (lactic and acetic acids) was performed using a Shimadzu HPLC apparatus model LC-10AT (Shimadzu Corporation, Japan) consisting of an autosampler SIL-10AT, a column oven CTO-10AS, a system controller SCL-10A, equipped with a Refractive Index (RI) detector RID-10A, and an Ultra Violet (UV) detector SPD-10A. The injection volume of the samples was 20 μL and sample analysis was performed in duplicate for each sample and repeated two times ($n = 4$).

Chromatographic separation of organic acids was performed using a Rezex ROA-Organic Acid column (8 μm particle size, 300 \times 7.8 mm) (Phenomenex Inc., Torrance, CA, USA) with UV detection at 210 nm. The mobile phase was 0.005 N H_2SO_4 (Fisher Scientific, UK) using a flow rate of 0.5 mL/min, and column temperature of 20 °C.

The chromatographic data was collected and processed using Shimadzu LC Solution Software (Shimadzu Corporation, Japan). Standards for lactic acid were prepared at concentrations of 0.006%, 0.015%, 0.03%, 0.06%, 0.10%, 0.12%, and 0.15% (w/v). Standards for acetic acid were prepared at concentrations of 0.005%, 0.01%, 0.015%, 0.02%, 0.05%, 0.075% and 0.10%

(w/v). Calibration curves for sugar and organic acid standards were prepared to enable determination of the organic acid concentrations in the sourdough samples.

3.4.5 Quantification of FODMAPs in GF sourdough starter, bread dough, and bread samples by HPAEC-PAD and enzymatic assay

3.4.5.1 Analysis of FODMAPs in GF sourdough starter, bread dough, and bread samples by HPAEC-PAD

The FODMAPs in the GF sourdough starter (UD, FD), bread dough (BP, AP) and bread (after baking) samples of the Control and the reformulated GF sweet potato sourdough breads were analysed by HPAEC-PAD using the procedures described in Section 3.2.4. The test samples were frozen at -20 °C and lyophilised using a Labconco FreeZone 6 Freeze Dry System (Labconco, Kansas, MO) then ground to powder using a laboratory mill and sealed in stomacher bags prior to analysis of FODMAPs. The FODMAP analysis was performed in duplicate for each sample (n = 2).

3.4.5.2 Analysis of total fructans in GF sourdough starter, bread dough, and bread samples by enzymatic assay

The total fructans in GF sourdough starter (UD, FD), bread dough (BP, AP) and bread (after baking) samples of the Control and the reformulated GF sweet potato sourdough breads were analysed using the Megazyme Fructan HK Assay Kit (Megazyme International Ireland Ltd., Wicklow, Ireland) as described in Section 3.2.5. The total fructans of each sample was analysed in duplicate for each sample (n = 2).

3.5 Phase 4: Characterisation of the Control and the Reformulated GF Sweet Potato Sourdough Breads

3.5.1 Loaf volume

The loaf weight of each bread sample was recorded immediately after baking, and the volume was measured using the AACC International Method 10-05.01 rapeseed displacement method (AACC, 2000). The specific volume of bread was calculated according to Equation 7:

$$\text{Specific volume (cm}^3\text{/g)} = \frac{\text{Loaf volume (cm}^3\text{)}}{\text{Loaf weight (g)}} \dots\dots\dots \text{Equation 7.}$$

3.5.2 Baking weight loss

The baking weight loss of all the bread samples were determined immediately after baking and calculated by the difference in weight of the dough before and after baking. The baking weight loss (%) was calculated based on Equation 8:

$$\text{Baking weight loss (\%)} = \frac{\text{Weight of dough (g)} - \text{Weight of bread (g)}}{\text{Weight of dough (g)}} \times 100\% \dots\dots\dots \text{Equation 8.}$$

3.5.3 Water activity

The water activity (A_w) of all the fresh made bread samples (Day 0) and at 7 days of storage (Day 7) were measured in triplicate after cooling (1 h) at room temperature (20 °C) using the Novasina SPRINT-TH 500 water activity meter (Novasina, Pfäffikon, Switzerland). Prior to measurement, the meter was calibrated with the Novasina SAL-T humidity standard (90 % relative humidity). The center of the bread slices were removed (10 mm thickness x 40 mm diameter) and placed in polypropylene sample dishes (Novasina, Pfäffikon, Switzerland) for up to 72 h during which time water activity data were recorded until constant readings were obtained.

3.5.4 Texture profile analysis (TPA)

Texture analysis of the fresh bread crumb samples (at Day 0) was performed according to the AACCI International Method 74-09.01 (AACCI, 2010b). Texture profile analysis of the crumb samples was measured using the TA-XT Plus Texture Analyser (Stable Microsystems, Godalming, UK) equipped with a 30-kg load cell and a 31-mm diameter aluminium cylindrical probe. The probe was set at a speed of 1.7 mm/s to compress the middle of the crumb to 40% of its original height. The time between the compressions was set to 5 s. The following parameters were measured: hardness (maximum force of the first compression), cohesiveness (area of work during the second compression divided by the area of work during the first compression), and springiness (distance of the detected height during the second compression divided by the original compression distance). Two slices of bread ($12.5 \text{ mm} \times 2 = 25 \text{ mm}$ thickness) taken from the center of each loaf were used for texture profile analysis.

3.5.5 Crumb and crust colour

The crumb and crust colour of the fresh bread samples (at Day 0) were measured with a Minolta Chroma meter model CR-300 (Minolta Camera Co. Ltd, Osaka, Japan), using a CIE $L^* a^* b^*$ colour scale following the manufacturer's instructions. The CIE $L^* a^* b^*$ colour space is composed of three coordinates: L^* , a^* , and b^* . The L^* value represents the lightness of the colour ($L = 100$ white colour, $L = 0$ black colour), the a^* value represents the position of the colour between green and red ($-a^*$ greenness, $+a^*$ redness), the b^* value represents the position of the colour between blue and yellow ($-b^*$ blueness, $+b^*$ yellowness). Prior to colour measurement of the samples, a Minolta white porcelain plate ($L^* = 97.10$, $a^* = -0.07$, $b^* = 1.97$) was used to standardise the instrument. Three different positions randomly chosen from the whole crust piece and crumb of each of the bread loaf were measured and three consecutive colour measurements were obtained for each position ($n = 9$).

3.5.6 Microbiological analysis of bread samples

Yeast and mould counts and total aerobic plate counts (APC) of the fresh bread samples (Day 0, stored at room temperature) were determined prior to sensory evaluation to assure safety in accordance with the Human Ethics approval (Application ID: 4000021503). Ten grams of each bread sample was homogenised with 90 mL sterile peptone solution (0.1 %) (Merck, Darmstadt, Germany) in a stomacher bag (LABPLAS, Quebec, Canada) using a 400-mL Masticator lab paddle blender (IUL Instruments, Barcelona, Spain) for 2 min. The sample homogenates were subjected to serial dilutions up to 10^{-4} . One milliliter aliquot from each diluted sample was plated on YGC agar (Merck, Darmstadt, Germany) for yeasts and moulds, and APC were enumerated on Plate Count Agar (PCA) (BD Diagnostics, Sparks, MD, USA). The plates for yeasts and mould count were incubated at 25 °C for 5 days, and the plates for APC were incubated at 37 °C for 48 h (Ijah et al., 2014). After incubation, any grown colonies on the plates were counted using a colony counter (Bibby Scientific Ltd, Staffordshire, UK). The results were expressed as colony forming units (CFU) per gram of bread sample.

3.5.7 Sensory evaluation

Consumer sensory evaluation of the Control and the reformulated GF sweet potato sourdough breads were carried out in individual sensory booths at room temperature (20 °C) under white light at the Sensory Evaluation Laboratory (School of Food and Advanced Technology, Massey University Albany campus). Consumer panelists (n = 50) were randomly recruited at Massey University Albany campus. The sensory attributes (appearance, aroma, flavour, texture, overall acceptability) of all bread samples were evaluated using a 9-point hedonic scale with descriptive anchors labeled at the ends with ‘dislike extremely’ and ‘like extremely’. One slice of bread (12.5 mm thickness) was taken from the center of each loaf and randomly assigned a three-digit code prior to being presented to consumer sensory participants for evaluation of its attributes. Distilled water and plain crackers were used to clean the palate between samples.

Responses were recorded on a questionnaire provided to each sensory panelist (as shown in Appendix B).

3.6 Data Analysis

Raw data obtained in this study are presented as mean \pm standard deviation (SD) as shown in Appendix C. Statistical analysis of data was performed using the SPSS Version 26 (IBMTM Company, USA). One-way analysis of variance (ANOVA) was used to determine the effect of bread formulation, amount of sourdough starter added and fermentation condition on the FODMAP concentrations, physico-chemical, microbiological, and sensory properties of the bread samples at $p \leq 0.05$ for significance. Tukey's HSD test was used to determine significant differences between samples for all measurements at $p \leq 0.05$. All statistical outputs obtained from data analysis are shown in Appendix D.

CHAPTER 4 RESULTS AND DISCUSSION

4.1 Quantification of FODMAPs in Commercial Gluten-free Breads

4.1.1 Introduction

In phase 1, the FODMAP content (including total fructans) of seven commercial GF breads (described in Section 3.1.1) were quantified by high-performance anion-exchange chromatography coupled with pulsed amperometric detection (HPAEC-PAD) and enzymatic assay using the methods described in Section 3.2. The levels of each subgroup of FODMAPs (monosaccharides, sugar polyols, GOS, FOS and total fructans) in the commercial GF breads were compared to the cut-off levels (g per serve) recommended for the low-FODMAP food criteria (Varney et al., 2017) described in Section 2.3.2. Based on the results obtained in this phase, the bread formulation of GF sweet potato sourdough bread (GFSD1) containing the highest amounts of FODMAPs was selected as the Control formulation for phase 2 of this study which aimed at reducing the FODMAPs in the existing products through reformulation of the existing bread formulation and retard proofing.

4.1.2 Chromatogram profiles of FODMAP standards and bread sample

A typical chromatogram of a mixture of FODMAP sugar standards separated by HPAEC-PAD using the Dionex CarboPac PA20 column is shown in Figure 10. The chromatogram shows the peaks of eight FODMAP sugars of interest to this study which included sugar polyols (sorbitol, mannitol), monosaccharides (glucose, fructose), GOS (raffinose, stachyose), and FOS (kestose, nystose), as well as the internal standard sugar (rhamnose). As shown in Figure 10, the peaks are numbered in order of elution and their corresponding retention times.

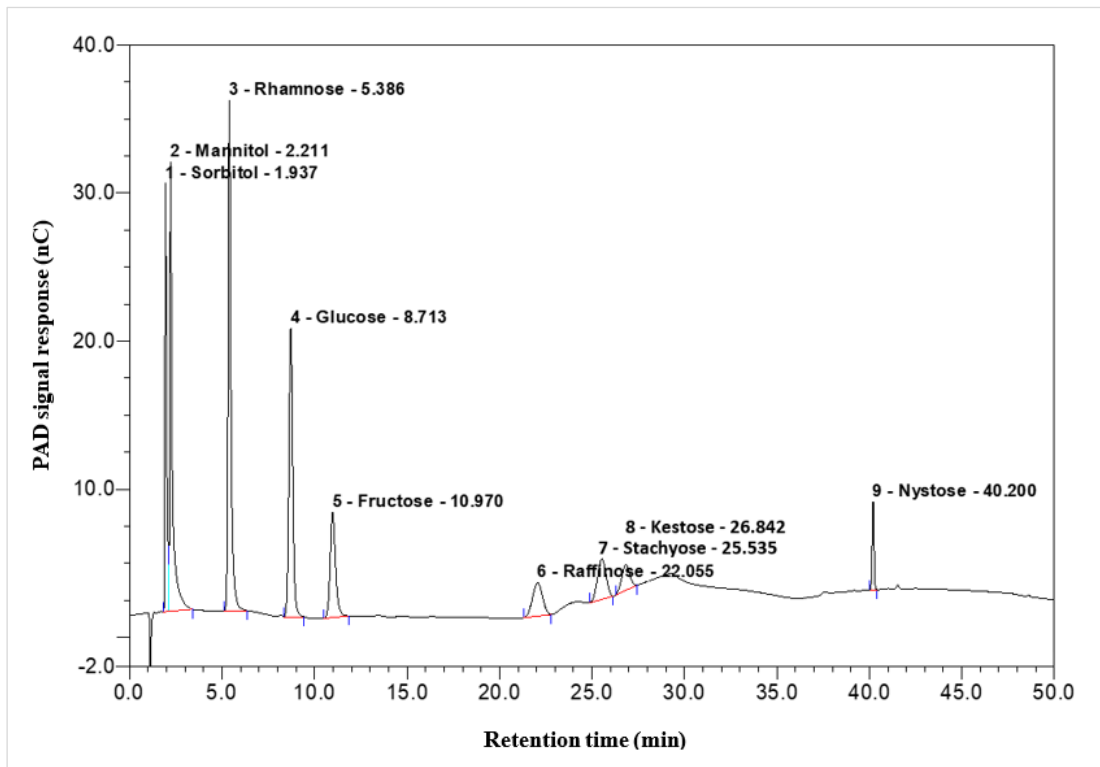


Figure 10 HPAEC-PAD chromatogram profile of a mixture of FODMAP sugar standards separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times.

The results indicate that HPAEC coupled with PAD provided sufficient resolution and sensitivity to quantify monosaccharides, oligosaccharides and sugar polyols (Lee, 1996; Montero et al., 2004; Brummer & Cui, 2005), which could be used to quantify major FODMAP sugars present in foods (Ziegler et al., 2016; Ispiryan et al., 2019; Ispiryan, Zannini & Arendt, 2020). Lactose (disaccharide), a major FODMAP sugar present in dairy products (Fedewa & Rao, 2014), was not analysed in the current study as all the commercial GF breads selected for this study were made from dairy-free ingredients. An example of a chromatogram profile of FODMAP sugars from the gluten-free sourdough bread sample 1 (GFSD1) is shown in Figure 11.

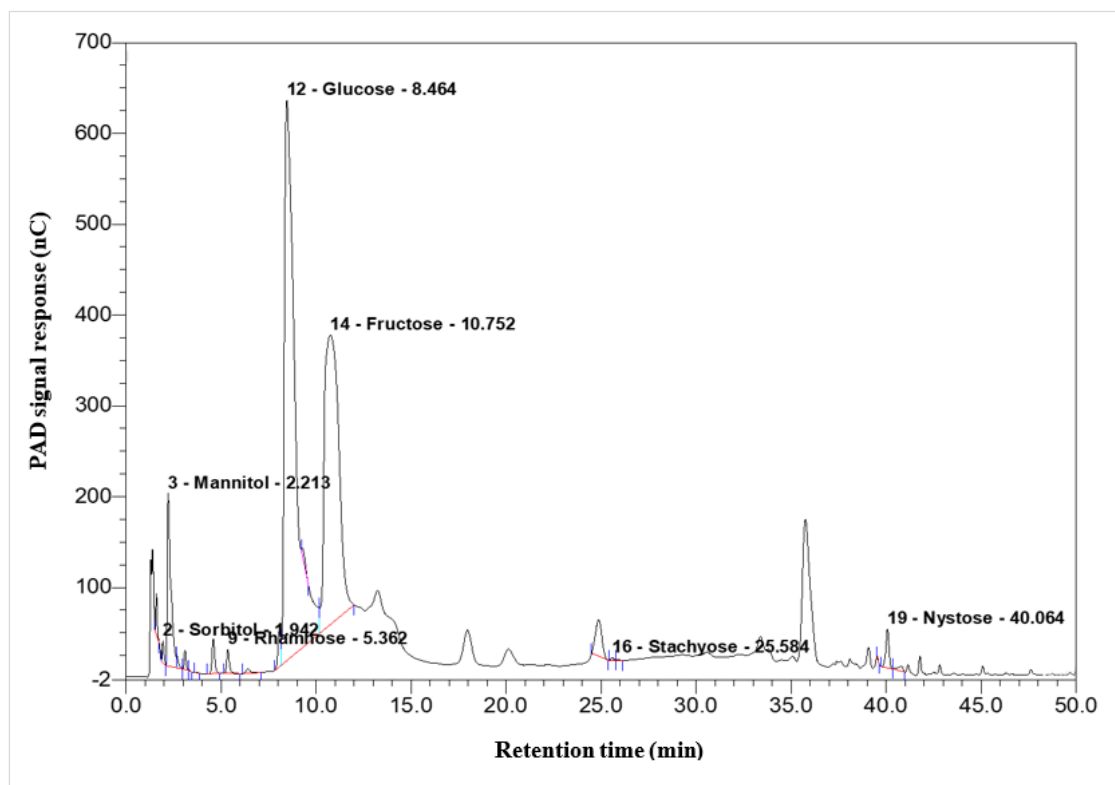


Figure 11 HPAEC-PAD chromatogram profile of FODMAP sugars from the gluten-free sourdough bread sample 1 (GFSD1) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

4.1.3 Calibration curves, detection and quantification limits, and repeatability of the method

The signal responses of standard solutions of different concentrations were determined and calibration curves were obtained by plotting the PAD signal response (nC) against concentration (mg/L) (Table 9). The linearity of the calibration curves, expressed as the determination coefficient (R^2) was studied using five concentrations in the linear range of 0.20 - 2.00 mg/L. All the calibration curves showed good linearity ($R^2 = 0.9984 - 0.9999$) within the concentration range tested. The limit of detection (LOD) and limit of quantification (LOQ) were estimated using the signal-to-noise ratio (S/N) (Snyder, Kirkland & Dolan, 2010). The LOD of the sugars ranged from 0.02 - 0.10 mg/L (S/N = 3), and the LOQ of the sugars ranged from 0.03 - 0.15 mg/L (S/N = 5). The relative standard deviation

(% RSD) from six injections of standard sugars were in the range of 1.62 - 4.66 %. Based on these results, the method used in current study was considered as accurate (% RSD less than 5 %) and sufficiently sensitive to simultaneously analyse the content of major FODMAPs present in the bread products.

Table 9 Calibration curve, linearity, limit of detection (LOD) and limit of quantification (LOQ), and repeatability (% RSD) of the major FODMAP sugars

Sugar	Calibration Curve	Determination Coefficient (R ²)	LOD (mg/L)	LOQ (mg/L)	% RSD
Sorbitol	$y = 1.2932 x + 0.1408$	0.9985	0.05	0.08	3.18
Mannitol	$y = 1.3534 x + 0.1469$	0.9984	0.05	0.08	3.49
Glucose	$y = 1.0158 x + 0.0392$	0.9997	0.02	0.03	2.45
Fructose	$y = 0.3826 x + 0.0101$	0.9999	0.05	0.08	1.62
Raffinose	$y = 0.1041 x + 0.0103$	0.9992	0.10	0.15	3.84
Stachyose	$y = 0.1315 x + 0.0090$	0.9990	0.10	0.15	4.51
Kestose	$y = 0.0857 x + 0.0050$	0.9994	0.10	0.15	3.59
Nystose	$y = 0.2888 x + 0.0186$	0.9989	0.10	0.15	4.66

y = PAD signal response (nC); x = concentration (mg/L); LOD = limit of detection; LOQ = limit of quantification; % RSD = relative standard deviation; Linear range = 0.20 - 2.00 mg/L; $n = 6$.

4.1.4 FODMAP content of commercial gluten-free breads

The FODMAP content of seven commercial GF breads quantified by HPAEC coupled with PAD, and total fructans measured by enzymatic assay are shown in Table 10. All GF breads contained fructans, fructose, glucose, sorbitol and nystose. Mannitol was detected in all GF breads except in GF2. Stachyose was detected in six GF breads but not in GF1, while raffinose was only detected in three samples (GF3, GFSD3 and GFSDNY). Kestose was not detected in any of the GF breads tested. Findings from this study on the major FODMAPs present in GF bread were similar to those reported by Biesiekierski et al. (2011), who also suggested that the FODMAP content of breads are dependent on the grains and ingredients used for their manufacture (Whelan et al., 2011; Ispiryan, Zannini & Arendt, 2020).

Table 10 FODMAP content of seven commercial GF breads

Sample	Sample Size	FODMAPs by HPAEC with PAD (g per 100 g as consumed weight and g per serve*)									Total Fructans by Enzymatic Assay (g per 100 g as consumed weight and g per serve*)
		Monosaccharides			Sugar Polyols			GOS	FOS		Total Fructans
		Fructose	Glucose	Excess Fructose	Sorbitol	Mannitol	Raffinose	Stachyose	Nystose	Kestose	
GFYF1	g per 100 g as consumed weight	0.128 ± 0.005	0.107 ± 0.006	0.021 ± 0.000	0.039 ± 0.002	0.014 ± 0.001	ND	ND	0.018 ± 0.001	ND	0.0788 ± 0.0028
	g per 66 g (two slices)	0.084 ± 0.004	0.071 ± 0.004	0.014 ± 0.000	0.026 ± 0.001	0.009 ± 0.001	ND	ND	0.012 ± 0.000	ND	0.0520 ± 0.0019
GFYF2	g per 100 g as consumed weight	0.162 ± 0.010	0.107 ± 0.005	0.055 ± 0.004	0.031 ± 0.001	ND	ND	0.009 ± 0.000	0.058 ± 0.004	ND	0.1202 ± 0.0029
	g per 73 g (two slices)	0.118 ± 0.007	0.078 ± 0.004	0.040 ± 0.003	0.023 ± 0.001	ND	ND	0.006 ± 0.000	0.042 ± 0.003	ND	0.0877 ± 0.0021
GFYF3	g per 100 g as consumed weight	0.178 ± 0.002	0.120 ± 0.004	0.058 ± 0.003	0.030 ± 0.001	0.001 ± 0.000	0.120 ± 0.006	0.056 ± 0.003	0.074 ± 0.004	ND	0.1815 ± 0.0015
	g per 73 g (two slices)	0.130 ± 0.001	0.087 ± 0.003	0.043 ± 0.002	0.022 ± 0.001	0.001 ± 0.000	0.088 ± 0.004	0.041 ± 0.002	0.054 ± 0.003	ND	0.1324 ± 0.0010
GFSD1	g per 100 g as consumed weight	0.194 ± 0.023	0.145 ± 0.012	0.050 ± 0.011	0.004 ± 0.000	0.034 ± 0.000	ND	0.005 ± 0.000	0.035 ± 0.002	ND	0.1085 ± 0.0015
	g per 100 g (one bun)	0.194 ± 0.023	0.145 ± 0.012	0.050 ± 0.011	0.004 ± 0.000	0.034 ± 0.000	ND	0.005 ± 0.000	0.035 ± 0.002	ND	0.1085 ± 0.0015
GFSD2	g per 100 g as consumed weight	0.174 ± 0.007	0.128 ± 0.006	0.046 ± 0.001	0.005 ± 0.000	0.034 ± 0.000	ND	0.007 ± 0.000	0.033 ± 0.001	ND	0.0711 ± 0.0015
	g per 73 g (two slices)	0.127 ± 0.005	0.094 ± 0.004	0.034 ± 0.001	0.004 ± 0.000	0.025 ± 0.000	ND	0.005 ± 0.000	0.024 ± 0.001	ND	0.0519 ± 0.0011
GFSD3	g per 100 g as consumed weight	0.081 ± 0.003	0.112 ± 0.009	0	0.003 ± 0.000	0.026 ± 0.000	0.036 ± 0.000	0.005 ± 0.000	0.020 ± 0.002	ND	0.0148 ± 0.0016
	g per 40 g (one slice)	0.032 ± 0.001	0.045 ± 0.004	0	0.001 ± 0.000	0.011 ± 0.000	0.014 ± 0.000	0.002 ± 0.000	0.008 ± 0.001	ND	0.0059 ± 0.0006
GFSDNY	g per 100 g as consumed weight	0.029 ± 0.000	0.132 ± 0.002	0	0.001 ± 0.000	0.033 ± 0.000	0.018 ± 0.000	0.015 ± 0.000	0.027 ± 0.000	ND	0.0546 ± 0.0026
	g per 40 g (one slice)	0.012 ± 0.000	0.053 ± 0.001	0	0.000 ± 0.000	0.013 ± 0.000	0.007 ± 0.000	0.006 ± 0.000	0.011 ± 0.000	ND	0.0218 ± 0.0010

GFYF = gluten-free yeast-fermented; GFSD = gluten-free sourdough-fermented; GFSDNY = gluten-free sourdough-fermented without yeast added; GOS = galactooligosaccharides; FOS = fructooligosaccharides; Excess fructose = fructose - glucose; ND = not detected; n = 2.

In this study, fructans were found to be the major FODMAPs present in the GF breads tested, ranging from 0.0148 g/100 g (GFSD3) to 0.1815 g/100 g (GF3). The highest amount of total fructans (g per 100 g as consumed weight) were present in GF3 (0.1815 g) > GF2 (0.1202 g) > GFSD1 (0.1085 g) > GF1 (0.0788 g) > GFSD2 (0.0711 g) > GFSDNY (0.0546 g) > GFSD3 (0.0148 g). These results were similar to the study by Biesiekierski et al. (2011), who reported the total fructan content of GF bread to be 0.19 g per 100 g, which is much lower than that of white wheat bread (0.68 g/100 g). The results are also consistent with a study by Korus et al. (2006), which reported negligible presence of fructans in GF breads made from corn and potato starch. The fructan levels of the main ingredients of most GF breads (e.g. brown rice flour, corn starch, potato starch, quinoa, buckwheat) are lower than 0.1 g/100 g dry weight, thus GF breads are generally low in total fructans (Ispiryan, Zannini & Arendt, 2020), although differences in ingredients and manufacturing processes may also affect the fructan content of the final breads (Whelan et al., 2011; Ziegler et al., 2016). In this study, GF2 and GF3 contained the highest levels of fructans, probably due to the addition of honey. Honey is considered as a natural compound rich in prebiotic fructo-oligosaccharides and therefore it is potentially high in fructans (Erejuwa, Sulaiman & Wahab, 2012; Anonymous, 2019). Yeast fermentation may also have contributed to the degradation of fructans in the GF breads (Struyf, Verspreet & Courtin, 2018), with the exception of the GFSDNY, which was produced without the addition of yeast. The relatively lower levels of fructans in GF sourdough breads (GFSD3 and GFSDNY) may be due to the enzymatic degradation of fructans by LAB and yeast during sourdough fermentation (Tsujikawa, Nomoto & Osawa, 2013).

Although all the GF breads in this study contained glucose and fructose, excess fructose (excess fructose = fructose - glucose) (g per 100 g) was found in five samples: GF3 (0.058 g), GF2 (0.055 g), GFSD1 (0.050 g), GFSD2 (0.046 g) and GF1 (0.021 g). These results were higher than the findings of Ispiryan, Zannini and Arendt (2020), who reported no excess fructose in a GF white loaf. The presence of excess fructose in the GF breads analysed in this study was expected as the formulation contained honey, coconut flour and coconut sugar, which are high in fructose (Ladas, Haritos & Raptis, 1995; Fernández-Bañares et al., 2006; Monash University, 2019). However, the excess fructose levels were lower than those reported for GF bread made from rice, corn and tapioca flour (0.24 g per 100 g) (Biesiekierski et al., 2011).

In addition to the effect of the ingredients in the formulation, the amount of excess fructose remaining in the breads was also dependent on the fermentation process and fermentation time (Ziegler et al., 2016; Loponen & Gänzle, 2018; Menezes et al., 2019). Degradation of fermentable carbohydrates (e.g. sucrose, fructans, and raffinose) in the dough by yeast invertase results in an initial increase of fructose during yeast-dough fermentation, followed by an almost complete depletion of fructose after 2 h fermentation (Verspreet et al., 2013). Conversion of digestible carbohydrates (e.g. sucrose and raffinose) by fructosidases or levansucrase from LAB during sourdough fermentation leads to the release of fructose, which can be readily fermented or converted to mannitol by LAB in the later stage of fermentation (Loponen & Gänzle, 2018).

Sorbitol was present in all the GF breads tested in this study, ranging from 0.001 g/100 g (GFSDNY) to 0.039 g/100 g (GF1). Mannitol was found in six of the GF bread samples, ranging from 0.001 g/100 g (GF3) to 0.034 g/100 g (GFSD1 and GFSD2). These results are consistent with another study, which reported that only trace amounts of sorbitol and mannitol were detected in GF bread (Biesiekierski et al., 2011). The sorbitol levels (g per 100 g as consumed weight) in the GF sourdough breads (GFSDNY 0.001 g < GFSD3 0.003 g < GFSD2 0.005 g < GFSD1 0.004 g) were lower than those in conventional GF breads (GF3 0.030 g < GF2 0.031 g < GF1 0.039 g). In contrast, GF sourdough breads contained higher amounts of mannitol (GFSD1 and GFSD2 0.034 g > GFSDNY 0.033 g > GFSD3 0.026 g) than conventional GF breads (GF1 0.014 g > GF3 0.001 g). Menezes et al. (2019) reported that mannitol levels increase during sourdough fermentation due to the conversion of fructose to mannitol by mannitol dehydrogenase by heterofermentative LAB.

Raffinose was only detected in three GF breads, with GF3 (0.120 g/100 g) containing the highest amount, followed by GFSD3 (0.036 g/100 g) and GFSDNY (0.018 g/100 g). Stachyose was not detected in GF1, but was present in the other GF breads tested, ranging from 0.005 g/100 g (GFSD1 and GFSD3) to 0.056 g/100 g (GF3). Nystose was also detected in all the GF breads, ranging from 0.018 g/100 g (GF1) to 0.074 g/100 g (GF3). No kestose was detected in the GF breads. Biesiekierski et al. (2011) reported similar GOS and FOS levels (raffinose 0.14 g/100 g, nystose 0.09 g/100 g, kestose 0.07 g/100 g, but no stachyose

was detected) in white GF breads commercially produced in Australia. Of the seven GF breads tested, sample GF3 contained the highest levels of total GOS and FOS, presumably because almond flour and linseed were the major ingredients. Almonds from different cultivars have been previously reported to contain significant amounts of raffinose (0.71 - 2.11 g/100 g, dry weight) (Barreira et al., 2010). Furthermore, raffinose is the second most predominant sugar in flaxseed (linseed), comprising 38 % of the total soluble sugars (Wanasundara, 1995).

A comparison between the levels of individual FODMAP groups (monosaccharides, sugar polyols, GOS, FOS and total fructans) in the seven commercial GF breads and the cut-off levels (g per serve) recommended for a low FODMAP-diet is shown in Figure 12. Results show that all the commercial GF breads analysed in this study conformed to the low FODMAP criteria (Varney et al., 2017). The overall FODMAP content of the GF sourdough breads were lower than conventional GF breads, which agrees with Varney et al. (2017) who reported that the use of the sourdough culture together with a long fermentation time can lower the FODMAPs in bread products. Of the four GF sourdough breads analysed in the present study, GFSD1 contained the highest levels of FODMAPs. Therefore, the basic formulation of the GF sweet potato sourdough bread (GFSD1) was selected for use in Phase 2 of this study, which aimed to reduce the FODMAP content of the existing product through reformulation and retard proofing.

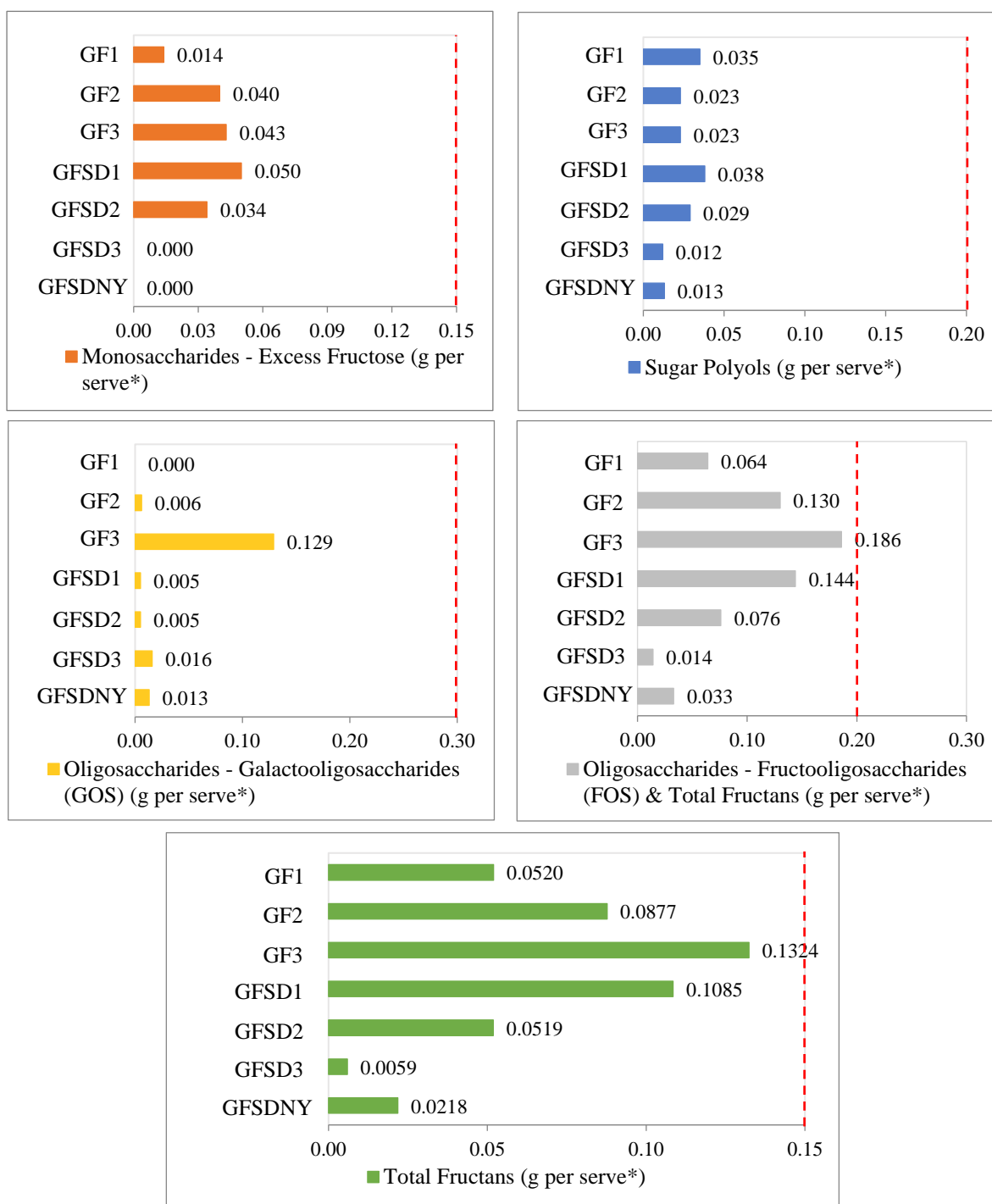


Figure 12 Comparison between the levels of individual groups of FODMAPs in commercial GF breads and the recommended cut-off levels (g per serve) for a low FODMAP-diet

*g per serve sizes were obtained from the nutritional panel as shown on the product packaging; GF1 = gluten-free bread sample 1 (GF White 495 g); GF2 = gluten-free bread sample 2 (GF Paleo Super Seeded 550 g); GF3 = gluten-free bread sample 3 (GF Paleo Almond & Linseed 550 g); GFSD1 = gluten-free sourdough bread sample 1 (GF Sweet Potato Sourdough Bread 300 g); GFSD2 = gluten-free sourdough bread sample 2 (GF Broken Black Rice & Polenta Sourdough Bread 550 g); GFSD3 = gluten-free sourdough bread sample 3 (GF Organic Sourdough Six Seed 600 g); GFSDNY = gluten-free sourdough bread without added yeast (GF Organic Sourdough Brown No Added Yeast 600 g); Excess fructose = fructose - glucose; Vertical red dotted lines = the cut-off levels (g per serving) of monosaccharides - excess fructose (0.15), sugar polyols (0.20), oligosaccharides - GOS (0.30), oligosaccharides - total fructans and FOS (0.20), and total fructans only (0.20); Cut-off levels for the FODMAPs are as per Varney et al. (2017); n = 2.

4.1.5 Summary of Phase 1

Results obtained from Phase 1 of this study showed that HPAEC-PAD with a Dionex CarboPac PA20 column provided high sensitivity and acceptable precision (% RSD < 5 %) for simultaneously analysing major FODMAPs in bread products. The major FODMAPs present in all seven commercial GF breads were fructans, excess fructose, sorbitol and nystose. Different grains and ingredients as well as the manufacturing processes used for making the GF breads resulted in differences in FODMAP content (monosaccharides, sugar polyols, GOS and FOS including total fructans). No kestose was detected in any of the GF breads. GF sourdough breads contained higher mannitol contents than conventional GF breads, presumably because of the conversion of fructose to mannitol during sourdough fermentation by mannitol dehydrogenase from the heterofermentative LAB. The overall FODMAP content of the GF sourdough breads were lower than conventional GF breads due to the activities of the sourdough culture and prolonged fermentation time, suggesting that sourdough fermentation could be used to further reduce the levels of FODMAPs in GF breads.

All seven commercial GF breads analysed in this study conformed to the low FODMAP criteria recommended by Varney and co-researchers (2017). Among the four GF sourdough breads analysed, GF sweet potato sourdough bread (GFSD1) contained the highest FODMAP content. Therefore, the basic formulation of GFSD1 was selected for Phase 2 of this study to reduce the levels of FODMAPs in the existing formulation of GF sweet potato sourdough bread through reformulation and retard proofing.

4.2 Characterisation of GF Sourdough Starter During Propagation

4.2.1 Introduction

Phase 2 of this study aimed to reduce the levels of FODMAPs in the existing formulation (Control) of GF sweet potato sourdough bread. Three reformulated GF sweet potato sourdough breads (RS, RS/RK and RS/ISD) by standard fermentation (1 h fermentation at 37 °C/87 % RH in the prover) and one bread using the same formulation as the Control but by retard proofing (12 h fermentation at 8 °C/87 % RH in the chiller) (Control/RP) were produced (as described in Sections 3.1.2, 3.1.3, and 3.3). The GF sourdough starters, bread doughs and bread samples of these GF sweet potato sourdough breads were sampled for analysis (the testing parameters are described in Section 3.1.4).

In phase 3, the microbiological (LAB and yeast counts) and physico-chemical characteristics (pH, TTA, organic acids) of the unfermented (UD 0 h) and fermented GF sourdough starters (FD 24 h, 48 h and 72 h) were determined over three days (72 h) of propagation using the methods described in Section 3.4. The FODMAPs (including total fructans) of the GF sourdough starter during propagation were quantified by HPAEC-PAD and enzymatic assay using the methods described in Section 3.4.5.

4.2.2 Characteristics of the GF sourdough starter

In this study, GF sourdough starter used for production of the Control and the reformulated GF sweet potato sourdough breads was produced by ‘refreshment’ of the mother sourdough starter with fresh brown rice flour, water and guar gum. The sourdough starter was propagated at 8 °C/87 % RH for 2 to 3 days, then used for sourdough bread production. After 48 h propagation, the sourdough starter (Figure 13) produced bubbles of gas within the batter structure and had a characteristic acidic and alcoholic smell consistent with a previous study (Wehrle & Arendt, 1998). The formation of the gas bubbles was likely caused by the increased amount of CO₂ in the sourdough starter, and the characteristic sourdough aroma was due to the flavorsome acids and alcohols produced during sourdough LAB and yeast fermentation (Lefebvre et al., 2002; Hansen & Schieberle, 2005; Rezaei et al., 2016).



Figure 13 Appearance of GF sourdough starter after 48 h propagation at 8 °C/87 % RH in the chiller
(Image was captured by iPhone 11 Pro, Apple Inc., USA)

Previous research on sourdough microbiota showed that LAB species, especially of the genus *Lactobacillus* and the yeast *Saccharomyces cerevisiae* were the predominant microorganisms in GF rice sourdoughs (Meroth, Hammes & Hertel, 2004; Corsetti & Settanni, 2007; De Vuyst & Vancanneyt, 2007; Park et al., 2017). The most frequently isolated LAB from GF rice sourdoughs are strains of *L. fermentum*, *L. plantarum*, *L. paralimentarius*, *L. paracasei*, and *L. pontis* (Meroth, Hammes & Hertel, 2004; De Vuyst et al., 2014). The diversity of sourdough microbiota is strongly associated with the flour type, the applied technology and fermentation process, as well as the geographic origin (De Vuyst & Neysens, 2005; De Vuyst & Vancanneyt, 2007; Vogel & Ehrmann, 2008).

4.2.3 LAB and yeast counts

The LAB and yeast counts of GF sourdough starter over three days (72 h) of propagation are shown in Figure 14. The initial LAB counts of the GF sourdough starter before fermentation (UD 0 h) from the mother sourdough was 8.29 ± 0.02 log CFU/g. After fermentation for 24 h, the cell density of LAB in the sourdough starter increased significantly ($p < 0.05$) to 8.59 ± 0.08 log CFU/g (FD 24 h), and then further to 9.43 ± 0.04 log CFU/g after 2 days of propagation (FD 48 h), after which the counts remained stable (FD 72 h) (9.45 ± 0.01 log CFU/g). These results are similar to other studies which reported the LAB cell counts of rice sourdoughs

ranged from 9.08-9.17 log CFU/g after propagation for 3-5 days (Meroth et al., 2004). Rapid growth of LAB is usually observed during the initial stage of propagation (1-2 days), and once the sourdoughs become mature, the counts stabilise for the subsequent propagation period (Van Der Meulen et al., 2007; Ercolini et al., 2013; Menezes et al., 2019).

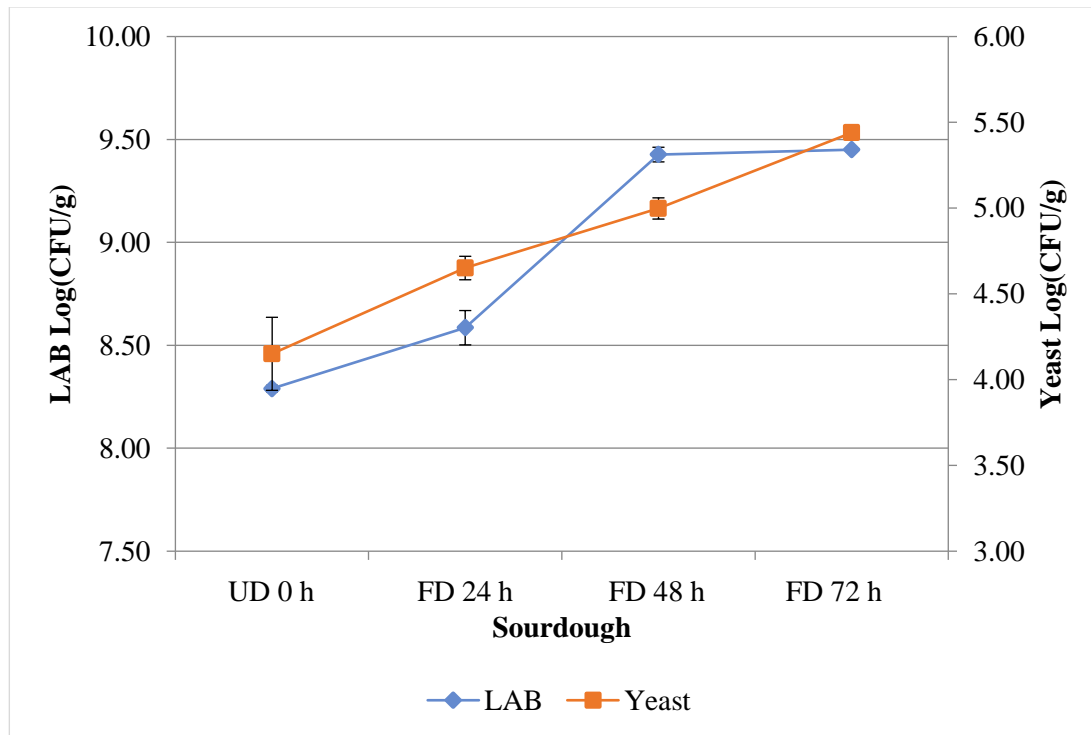


Figure 14 Lactic acid bacteria (LAB) and yeast counts of GF sourdough starter during 72 h propagation at 8 °C/87 % RH in the chiller

UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation; n = 2.

At the start of propagation, the unfermented sourdough starter (UD 0 h) contained 4.15 ± 0.21 log CFU/g yeast counts, and significantly ($p < 0.05$) increased to 4.65 ± 0.07 log CFU/g (FD 24 h) after the initial 24 h propagation and then increased over the following 2 days to 5.00 ± 0.06 log CFU/g (FD 48 h) and to 5.44 ± 0.01 log CFU/g (FD 72 h). These results are similar to the reported cell densities of yeasts in rice starter cultures (4.10-7.50 log CFU/g) during spontaneous fermentation (Hassen et al., 2018).

The growth rate, adaptability and yield of LAB and yeasts are governed by several ecological factors such as type and availability of fermentation substrates (e.g. carbohydrate and nitrogen sources), water activity, dough yield, redox potential, ionic strength, and metabolic products (e.g. CO₂, lactate, acetate, and ethanol) (Hammes & Gänzle, 1998; Hammes et al., 2005; De

Vuyst et al., 2017). The number of LAB and yeasts are consistent with those typically reported for mature sourdough starters, where the average cell density of LAB is 10^8 - 10^9 CFU/g and yeast counts range from 10^5 - 10^7 CFU/g (Gobbetti et al., 2008).

4.2.4 pH and total titratable acidity

The results of the pH and total titratable acidity (TTA) measurements of GF sourdough starter during 72 h of propagation are presented in Figure 15. The pH of the sourdough starter decreased and TTA increased during propagation, which is probably attributable to the production of organic acids during sourdough fermentation due to the metabolism of carbohydrates by LAB (Lefebvre et al., 2002; Corsetti & Settanni, 2007; Corsetti, 2013). The main factors that affect sourdough acidification are the amount of fermentable carbohydrates, the endogenous enzymatic activities of the flour, the species and growth rate of LAB, and the fermentation conditions (Gänzle, Ehrmann & Hammes, 1998; Wick et al., 2003; Leenhardt et al., 2005).

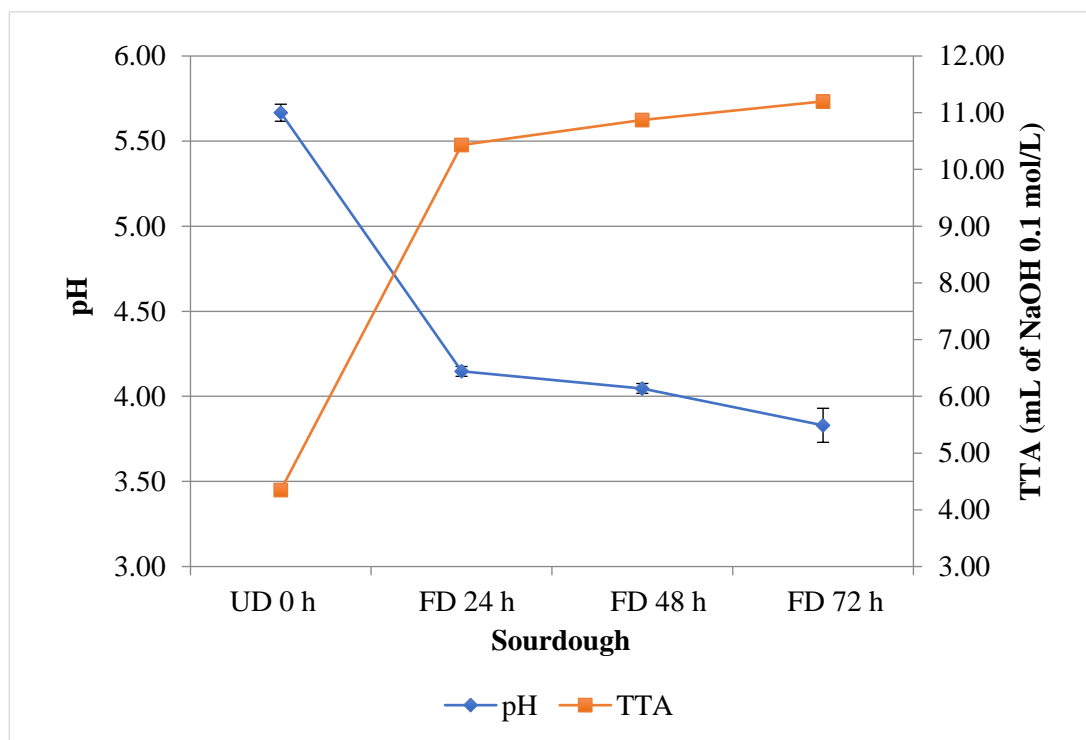


Figure 15 pH and total titratable acidity (TTA) of GF sourdough starter during 72 h propagation at 8 °C/87 % RH in the chiller

UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation; n = 3.

The pH of unfermented sourdough starter (UD 0 h) was 5.67 ± 0.02 , which decreased significantly ($p < 0.05$) during three days of propagation to 4.05 ± 0.02 after 48 h (before use for breadmaking) and to 3.83 ± 0.11 at the end of 72 h propagation. The pH results are similar to those reported for rice sourdoughs (pH 3.70-4.00) (Meroth et al., 2004) and brown rice sourdoughs made with *L. plantarum* and *L. sanfranciscensis* (pH 3.81-4.09) (Moore et al., 2007).

Total titratable acidity increased significantly ($p < 0.05$) from 4.35 ± 0.05 mL for the unfermented sourdough starter (UD 0 h) to 10.44 ± 0.03 mL (FD 24 h) after 24 h propagation and increased further to 10.88 ± 0.03 mL (FD 48 h) over the next 24 h propagation. The final TTA of the sourdough starter at the end of the propagation (FD 72 h) was 11.21 ± 0.10 mL. This result is similar to the reported TTA of 11.40 mL for rice sourdough after 3 days propagation (Meroth et al., 2004).

The acidification rate of the GF sourdough starter during the first 24 h of fermentation was faster than the following 48 h as reflected by the sharp decrease in pH from 5.67 ± 0.02 to 4.15 ± 0.02 and significant growth ($p < 0.05$) of the LAB cell density, supporting the active metabolism of LAB in the early stage of fermentation (Wehrle & Arendt, 1998). The acidification rate of GF sourdough starter reduced steadily during the following two days of propagation, accompanied by a minor decrease in pH, presumably because of the slowdown of growth and metabolic activities of LAB once the pH of the sourdough starter was lower than 4 and also due to the depletion of fermentable sugars (Thiele, Grassi & Gänzle, 2004; Paramithiotis et al., 2006).

4.2.5 Concentration of organic acids

The changes in the concentrations of organic acids in the GF sourdough starter during 72 h propagation are shown in Figure 16. The increase of lactic and acetic acid concentrations coincided with the growth of the sourdough community, resulting in the lowered pH and increase in TTA (Corsetti, 2013). The amounts of lactic and acetic acid produced during sourdough fermentation is dependent on the LAB species in the sourdough (Moore et al., 2007), with homofermentative strains such as *L. amylovorus* producing lactic acid via the glycolytic Embden-Mayerhoff Parnas (EMP) pathway. In contrast, heterofermentative strains such as *L. fermentum* and *L. plantarum* produce mainly lactic acid as well as significant amounts of acetic

acid by the phosphoketolase pathway (Corsetti & Settanni, 2007; Moore et al., 2007; Von Wright & Axelsson, 2011).

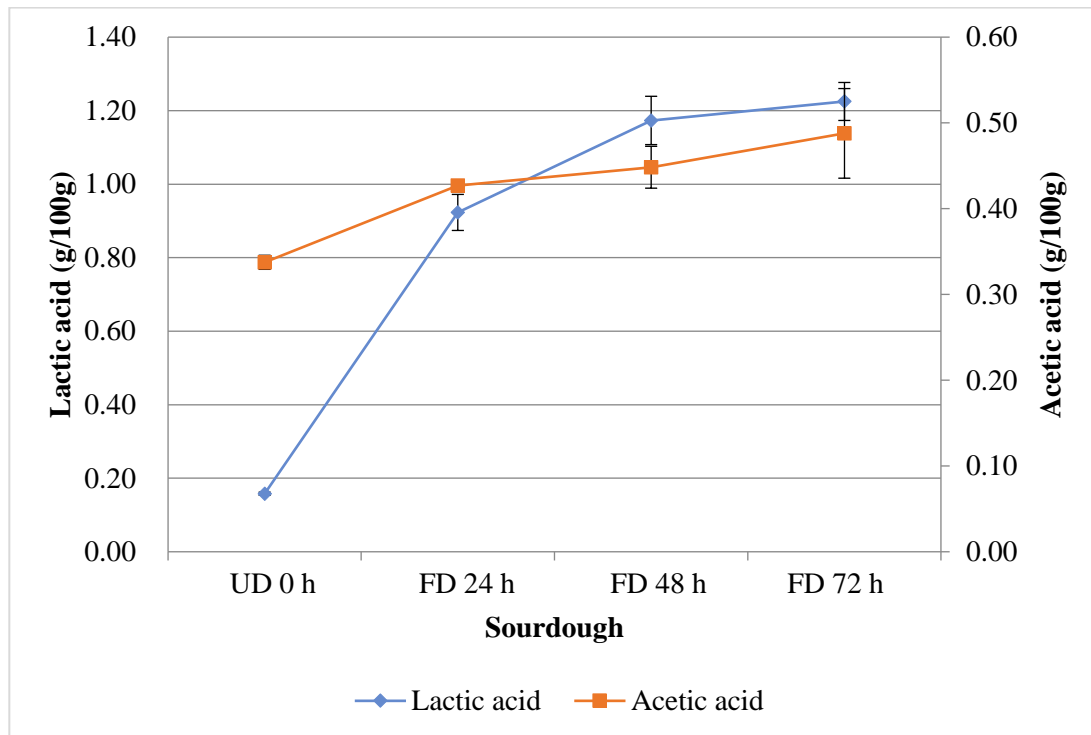


Figure 16 Lactic and acetic acid concentrations in GF sourdough starter during 72 h propagation at 8 °C/87 % RH in the chiller

UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation; n = 4.

The lactic acid concentration of the unfermented sourdough starter (UD 0 h) was 0.16 ± 0.00 g/100 g, which increased ($p < 0.05$) to 0.92 ± 0.05 g/100 g (FD 24 h) after the initial 24 h fermentation. The lactic acid concentration continued to increase over the following two days (1.17 ± 0.07 g/100 g for FD 48 h and reached 1.22 ± 0.05 g/100 g for FD 72 h). The level of lactic acid in the GF sourdough starter after 72 h fermentation at 8 °C in the present study was lower than that reported for wheat sourdough starter prepared by inoculation of single strains of *L. plantarum* and *L. brevis*, which had 1.6-1.7 g/100 g lactic acid in the sourdough after fermentation at 35 °C for 24 h (Salovaara & Valjakka, 1987). This difference is likely due to the higher fermentation temperature used in the latter study which resulted in a significantly higher level of lactic acid in the sourdough starter. The production of organic acids is influenced by the intensity of the metabolic activities of LAB, and different species of LAB have different optimal growth temperatures (Banu, Vasilean & Aprodu, 2011).

The acetic acid concentration of the unfermented sourdough starter (UD 0 h) was 0.34 ± 0.01 g/100 g, and sharply increased to 0.43 ± 0.00 g/100 g (FD 24 h) after 24 h propagation, then slightly increased to 0.45 ± 0.02 g/100 g (FD 48 h) after 48 h propagation. The final concentration of acetic acid in the sourdough starter after 72 h of propagation was 0.49 ± 0.05 g/100 g (FD 72 h), which is higher than previously reported (0.14-0.19 g/100 g) in wheat sourdoughs fermented by single strains of heterofermentative LAB (*L. plantarum*, *L. fermentum* and *L. brevis*) (Novotni et al., 2011). In the present study, the increase in acetic acid during propagation demonstrated the existence of heterofermentative strains of LAB in the GF sourdough starter (Martínez-Anaya, 2003). The synthesis of acetic acid is also affected by the presence of available electron acceptors such as fructose in the flour (Martínez-Anaya et al., 1994). Heterofermentation by LAB reduces fructose to mannitol and channels the metabolic pathway towards the acetate kinase reaction, which increases the production of acetic acid (Paramithiotis et al., 2006).

4.2.6 FODMAP content

The FODMAP content of the GF sourdough starters during propagation for three days (at 8 °C/87 % RH in the chiller) are shown in Table 11, and the HPAEC-PAD chromatogram profiles of FODMAPs from unfermented sourdough starter (UD 0 h) and fermented sourdough starter (FD 72 h) are shown in Figures 17 and 18. The results show that the sourdough starter made from GF brown rice flour contained very low levels of FODMAPs, and the propagation of sourdough exhibited the ability to further reduce any FODMAPs in the sourdough starter.

Fructose was rapidly consumed from the beginning of the propagation; the initial fructose concentration of the sourdough starter (UD 0 h) was 0.080 ± 0.005 g/100 g, which then decreased significantly ($p < 0.05$) to 0.007 ± 0.000 g/100 g (FD 24 h) and continued to decrease to 0.001 g/100 g (FD 72 h) at the end of the propagation. Glucose levels in the sourdough starter increased slightly during the early stages of sourdough propagation, from 0.099 ± 0.006 g/100 g (UD 0 h) to 0.106 ± 0.001 g/100 g (FD 24 h) and 0.114 ± 0.004 g/100 g (FD 48 h), then significantly ($p < 0.05$) reduced over the last 24 h to 0.068 ± 0.002 g/100 g (FD 72 h). Therefore, no excess fructose (excess fructose = fructose - glucose) was found in the sourdough starter samples. Findings from this study are similar to others who reported that fructose and glucose in wheat sourdough were rapidly consumed during the first stages of sourdough propagation (Menezes et al., 2019). Fructose and glucose are converted into organic acids by microbial

invertase activity and endogenous enzymatic activities (e.g. amylase) in flour during propagation (Neysens & De Vuyst, 2005; Loponen & Gänzle, 2018), hence their respective levels decrease.

Table 11 FODMAP content of GF sourdough starter during 72 h propagation at 8 °C/87 % RH in the chiller

Sourdough Sample	FODMAPs by HPAEC with PAD (g per 100 g as wet weight)									Total Fructans by Enzymatic Assay (g per 100 g as wet weight)
	Monosaccharides			Sugar Polyols		GOS		FOS		Total Fructans
	Fructose	Glucose	Excess Fructose	Sorbitol	Mannitol	Raffinose	Stachyose	Nystose	Kestose	
UD 0 h	0.080 ± 0.005 ^b	0.099 ± 0.006 ^b	0 ^a	0.003 ± 0.000 ^a	0.020 ± 0.001 ^a	0.052 ± 0.004 ^c	0.008 ± 0.000 ^a	0.026 ± 0.001 ^b	ND ^a	0.0164 ± 0.0013 ^c
FD 24 h	0.007 ± 0.000 ^a	0.106 ± 0.001 ^b	0 ^a	0.004 ± 0.000 ^b	0.032 ± 0.000 ^b	0.018 ± 0.000 ^b	0.032 ± 0.000 ^c	0.009 ± 0.000 ^a	ND ^a	0.0140 ± 0.0010 ^b
FD 48 h	0.002 ± 0.000 ^a	0.114 ± 0.004 ^b	0 ^a	0.004 ± 0.000 ^b	0.034 ± 0.001 ^b	0.007 ± 0.000 ^a	0.042 ± 0.002 ^d	0.011 ± 0.000 ^a	ND ^a	0.0109 ± 0.0013 ^b
FD 72 h	0.001 ± 0.000 ^a	0.068 ± 0.002 ^a	0 ^a	0.006 ± 0.000 ^c	0.033 ± 0.001 ^b	0.002 ± 0.000 ^a	0.020 ± 0.000 ^b	0.008 ± 0.000 ^a	ND ^a	0.0065 ± 0.0003 ^a

UD 0 h = unfermented sourdough starter; FD 24 h = sourdough starter after 24 h sourdough fermentation; FD 48 h = sourdough starter after 48 h sourdough fermentation; FD 72 h = sourdough starter after 72 h sourdough fermentation; GOS = galactooligosaccharides; FOS = fructooligosaccharides; Excess fructose = fructose – glucose; ND = not detected. ^{a-d}Values in the same column with different superscript letters differ significantly (p < 0.05); n = 2.

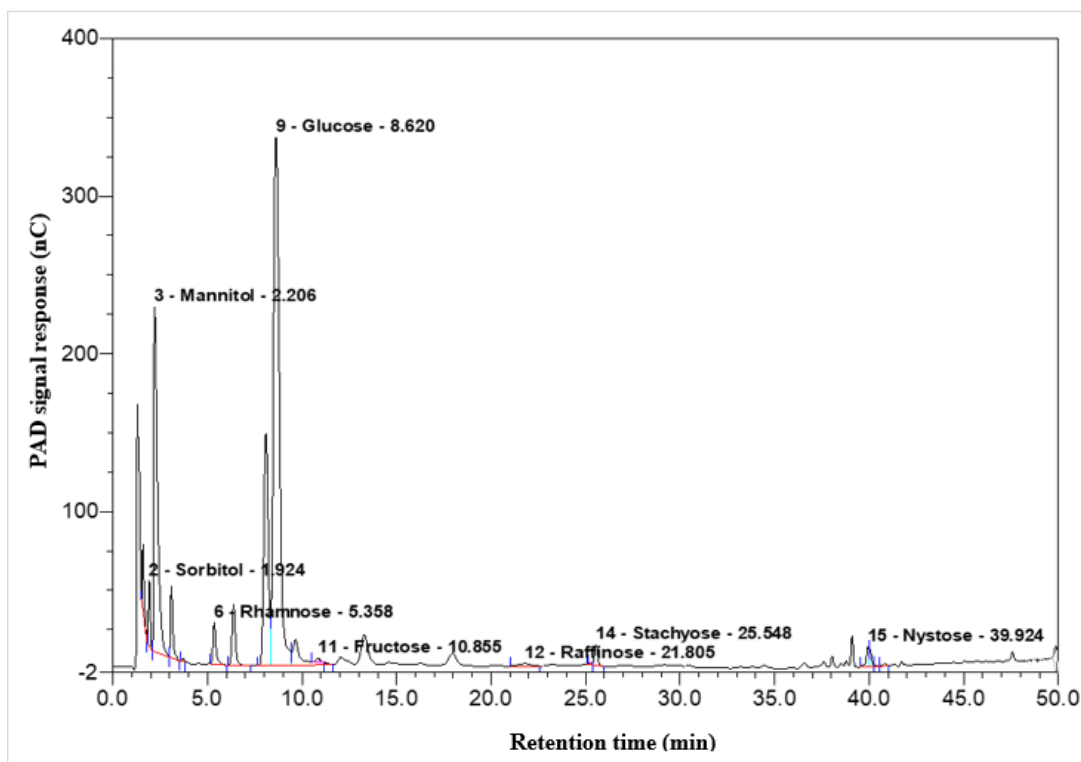


Figure 17 HPAEC-PAD chromatogram profile of FODMAPs from unfermented sourdough starter (UD 0 h) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

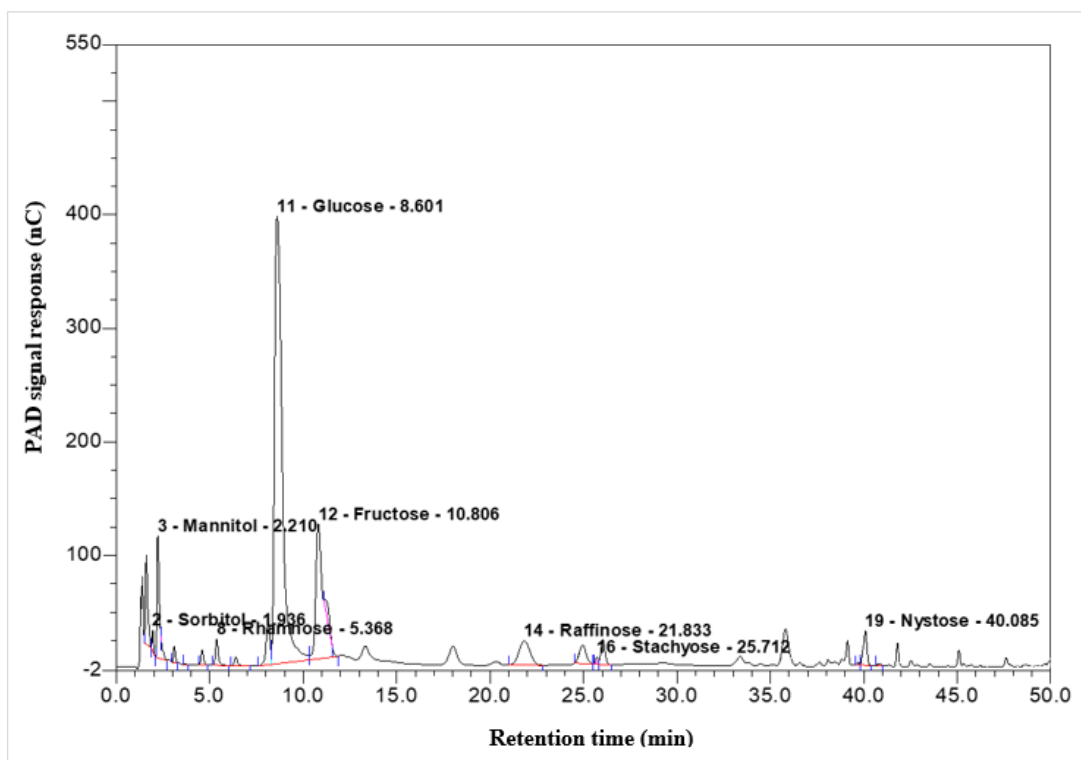


Figure 18 HPAEC-PAD chromatogram profile of FODMAPs from fermented sourdough starter (FD 72 h) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

The concentration of sorbitol in the unfermented sourdough starter (UD 0 h) was 0.0030 ± 0.0000 g/100 g, and mannitol was 0.0020 ± 0.0001 g/100 g. After 72 h propagation (FD 72 h), sorbitol and mannitol concentrations significantly ($p < 0.05$) increased to 0.0060 ± 0.0000 g/100 g and 0.0033 ± 0.0001 g/100 g, respectively. These results are consistent with previous reports that sorbitol and mannitol levels in wheat sourdough starter increased during the first three days of propagation (Menezes et al., 2019). The results from the current study indicate that there were heterofermentative LAB in the GF rice sourdough starter as these species (e.g. *L. brevis*) possess mannitol dehydrogenase and have the ability to produce mannitol, lactate and acetate using fructose as an electron acceptor during fermentation (Martinez, Barker & Horecker, 1963; Gobbetti, 1998).

The total concentration of GOS in the GF sourdough starter reduced during sourdough propagation as the raffinose concentration significantly ($p < 0.05$) decreased from 0.052 ± 0.004 g/100 g (UD 0 h) to 0.002 ± 0.000 g/100 g (FD 72 h). Meanwhile, a gradual increase in the stachyose concentration was observed from 0.008 ± 0.004 g/100 g (UD 0 h) to 0.042 ± 0.002 g/100 g (FD 48 h) after 48 h propagation, followed by a decrease to 0.020 ± 0.000 g/100 g at the end of propagation (FD 72 h). For FOS, the nystose concentration also reduced during sourdough propagation, from the initial 0.026 ± 0.001 g/100 g (UD 0 h) to a final concentration of 0.008 ± 0.000 g/100 g (FD 72 h). No kestose was detected in the sourdough starter samples. These results are in agreement with others (Gänzle & Follador, 2012; Loponen & Gänzle, 2018), who reported that GOS, FOS and raffinose-family oligosaccharides are degraded during sourdough fermentation through the activities of extracellular enzymes present in sourdough LAB (e.g. *L. reuteri*, *L. delbrueckii*, and *L. sanfranciscensis*), such as glucansucrases, fructansucrases, levansucrase and α -galactosidase. The enzymes catalyse the degradation of sucrose or large fractions of indigestible poly- or oligosaccharides, resulting in the liberation of short fractions of fermentable sugars, which can be easily metabolised by sourdough LAB or yeast through intracellular hydrolysis (Goh, Lee & Hutkins, 2007; Tsujikawa, Nomoto & Osawa, 2013).

The total fructans in the GF sourdough starter decreased consistently ($p < 0.05$) from 0.0164 ± 0.0013 g/100 g (UD 0 h) to 0.0065 ± 0.0003 g/100 g (FD 72 h) during propagation, similar to other reports (Fraberger et al., 2018). LAB that possess extracellular fructanases (e.g., *L. amylovorus*, *L. paracasei* and *L. casei*) can convert fructans (more than 4 degrees of

polymerisation) into fructose, which are then partially converted to mannitol (Loponen & Gänzle, 2018). Invertase produced by yeast *S. cerevisiae* has been reported to play a key role in the degradation of fructans during sourdough fermentation (Menezes et al., 2019).

4.2.7 Summary of Phase 2 and Phase 3

Four GF sweet potato sourdough breads (RS, RS/RK, RS/ISD and Control/RP) were developed in Phase 2 of this study through reformulation (by using low FODMAP ingredients, reducing high FODMAP constituent and increasing the amount of sourdough starter added) and retard proofing.

Results from Phase 3 of this study showed that the characteristics (pH, TTA, lactic and acetic acid content) and FODMAPs of GF sourdough starter were influenced by the duration of sourdough propagation. The sourdough starter used for producing the GF sweet potato sourdough breads (after 48 h propagation) produced gas bubbles in the batter structure and characteristic acidic and alcoholic smells due to the production of CO₂, organic acids and alcohols during fermentation of the sourdough by LAB and yeast. Accelerated growth of LAB was observed in the first 48 h of propagation, following which the LAB cell counts stabilised during the subsequent propagation possibly due to the depletion of available substrates. In contrast, the yeast cell counts continued to increase during propagation for 72 h. The decrease of pH and increase of TTA, lactic and acetic acid concentrations indicated the activities of sourdough LAB and yeasts during sourdough fermentation.

The GF sourdough starter used for this study was made from GF brown rice flour, therefore it contained very low amounts of FODMAPs. No excess fructose and kestose were found in the sourdough starter samples during any of the stages of propagation. The increase in sugar polyols (sorbitol and mannitol) indicated the presence of heterofermentative LAB in the GF sourdough starter, which possess mannitol dehydrogenase that can convert fructose to mannitol during sourdough fermentation. The overall FODMAP content of GF sourdough starter continued to reduce during propagation for 72 h. This was contributed to the degradation of oligosaccharides (raffinose, nystose and fructans) due to the activities of extracellular enzymes present in sourdough LAB and yeast invertase. The results from this study indicate the potential of prolonged sourdough propagation for further reduction of FODMAPs in sourdough starter.

4.3 Characterisation of Bread Dough and Bread Samples of the Control and the Reformulated GF Sweet Potato Sourdough Breads

4.3.1 Introduction

In phase 4, the microbiological (LAB and yeast counts) and physico-chemical properties (pH, TTA, organic acids) of the bread dough (before and after proofing) and bread samples of the Control and the reformulated GF sweet potato sourdough breads were determined using the methods described in Section 3.5. The FODMAPs (including total fructans) of the bread dough (before and after proofing) and bread samples were quantified by HPAEC-PAD and enzymatic assay using the methods described in Section 3.4.5.

4.3.2 LAB and yeast counts

The metabolic activities of sourdough LAB and yeast are responsible for the unique acidic flavour and superior textural and sensory qualities of sourdough bread (Paterson & Piggott, 2006; Arendt, Ryan & Dal Bello, 2007; Gobbetti et al., 2008). The numbers of LAB and yeast during the proofing process affect the acidification and leavening rate of the bread dough (Minervini et al., 2014). Microbiological analysis of bread doughs (before and after proofing) for all GF sweet potato sourdough breads are shown in Figures 19 and 20. As expected, the population of LAB and yeast grew significantly ($p < 0.05$) during proofing.

Before proofing, the number of LAB in the bread doughs ranged from 7.23 ± 0.16 log CFU/g (RS) to 8.05 ± 0.02 log CFU/g (RS/ISD), and the number of yeast ranged from 7.77 ± 0.12 log CFU/g (RS/RK) to 7.96 ± 0.01 log CFU/g (Control). According to Minervini et al. (2014), the microbial population present in the bread dough mainly reflects that of the sourdough starter, with the addition of flour and other ingredients causing a dilution of the LAB levels compared to the GF sourdough starter (FD 48 h, 9.43 ± 0.04 log CFU/g) used for bread production. In contrast, the yeast counts were significantly ($p < 0.05$) increased as baker's yeast was added in

the bread formulations of this study, which could promote the bread dough leavening and improve the bread characteristics (Meignen et al., 2001).

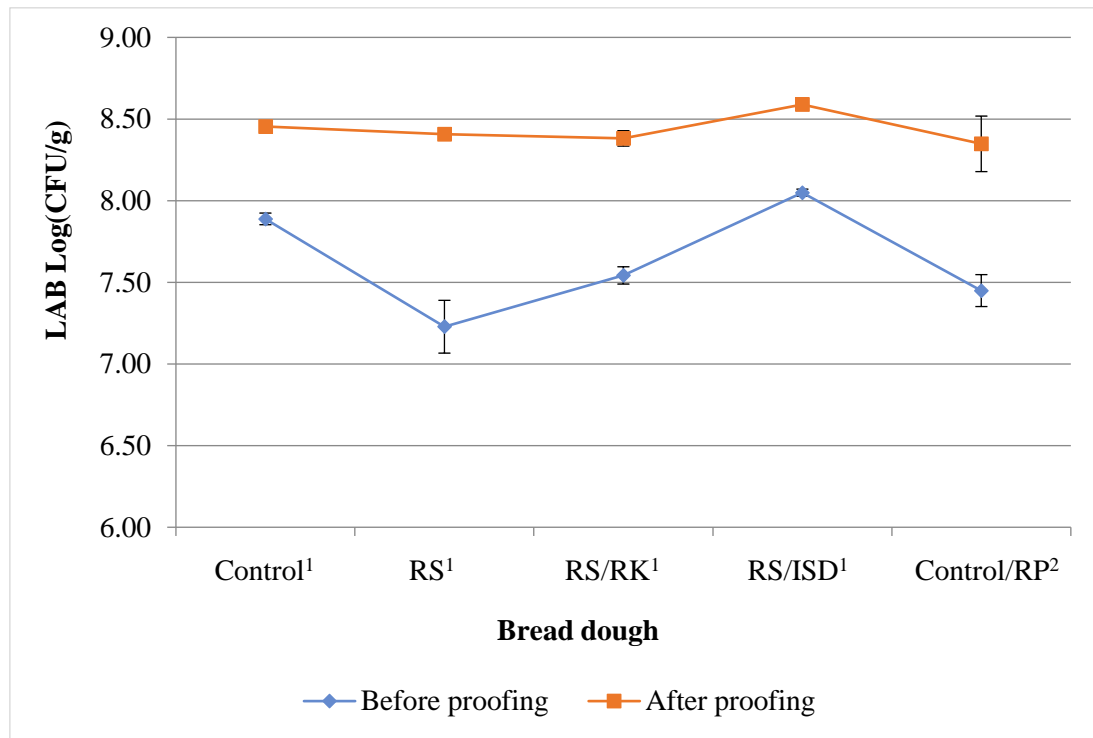


Figure 19 Lactic acid bacteria (LAB) counts of bread dough samples (before proofing and after proofing) of GF sweet potato sourdough breads by standard fermentation¹ or retard proofing²

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 2.

After proofing, the fermented bread doughs contained increased numbers of sourdough microbiota. LAB counts ranged from 8.35 ± 0.17 log CFU/g (Control/RP) to 8.59 ± 0.00 log CFU/g (RS/ISD), and yeast counts ranged from 8.21 ± 0.00 log CFU/g (RS) to 8.32 ± 0.02 log CFU/g (RS/ISD). The levels of LAB in the bread doughs after proofing were lower than reported for GF bread dough (made from rice flour, buckwheat flour, and corn starch) before baking, which contained 9.0 log CFU/g LAB counts (Di Cagno et al., 2008). The yeast counts were higher than the 7.09 - 7.76 log CFU/g reported for bread doughs used to produce Korean rice sourdough bread (Park et al., 2017). These variations are most likely due to differences in the formulations used for bread-making as well as the microbial composition of the sourdough starter (Corsetti & Settanni, 2007).

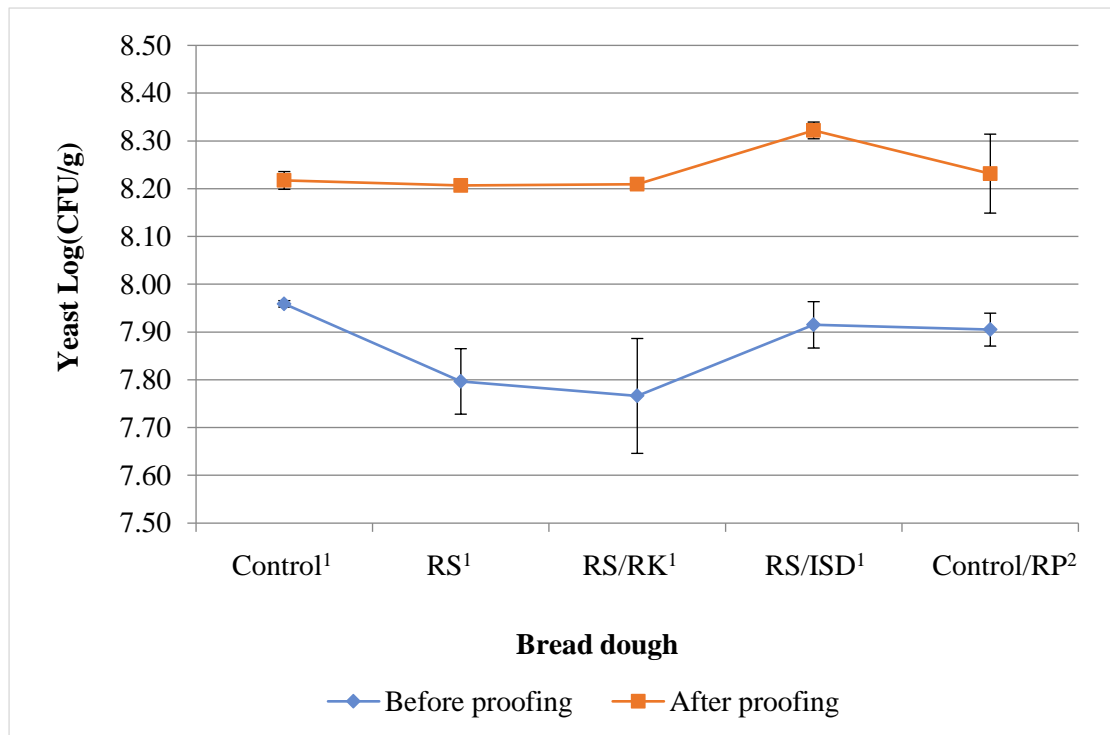


Figure 20 Yeast counts of bread dough samples (before proofing and after proofing) of GF sweet potato sourdough breads by standard fermentation¹ or retard proofing²

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 2.

Bread formulations and bread-making processes strongly influence the performance of sourdough starters and the microbiological growth during the sourdough process (Hammes & Gänzle, 1998; De Vuyst, Van Kerrebroeck & Leroy, 2017). The available fermentation substrates (e.g. carbohydrate and nitrogen sources), the activity of the cereal enzymes, the buffer capacity of the dough, and presence of other growth factors (e.g. micronutrients, minerals and vitamins) are all significantly affected by the flour components, ingredient types, sourdough concentration, and fermentation conditions (De Vuyst & Neysens, 2005; Hammes et al., 2005; Gänzle & Ripari, 2016).

As expected, the cell density of LAB in RS/ISD bread dough after proofing were significantly ($p < 0.05$) higher than the other bread doughs as additional sourdough starter was added. The cell density of LAB in the bread doughs increased with the increase in the amount of sourdough added into the formulations (Torrieri et al., 2004; Di et al., 2018). However, the LAB counts of the other bread dough formulations after proofing did not differ significantly ($p > 0.05$) from each other. These results indicate that although the growth rate of the sourdough LAB was

retarded at lower proofing temperature ($< 25\text{ }^{\circ}\text{C}$) (Brandt, 2015), similar levels of LAB cell density was obtained in the bread dough (Control/RP) after retard proofing (proofed at $8\text{ }^{\circ}\text{C}/87\text{ \% RH}$ for 12 h) compared to the other bread doughs (Control, RS and RS/RK) (proofed at $37\text{ }^{\circ}\text{C}/87\text{ \% RH}$ for 1 h).

4.3.3 pH and total titratable acidity

As shown in Figure 21, the pH of all the GF sweet potato sourdough bread doughs decreased during proofing ($p < 0.05$), while the TTA values increased. These changes were probably due to the production of organic acids by sourdough LAB through carbohydrate metabolism which contributes to the important characteristic acidic flavour and taste of sourdough products (Bartkiene et al., 2013).

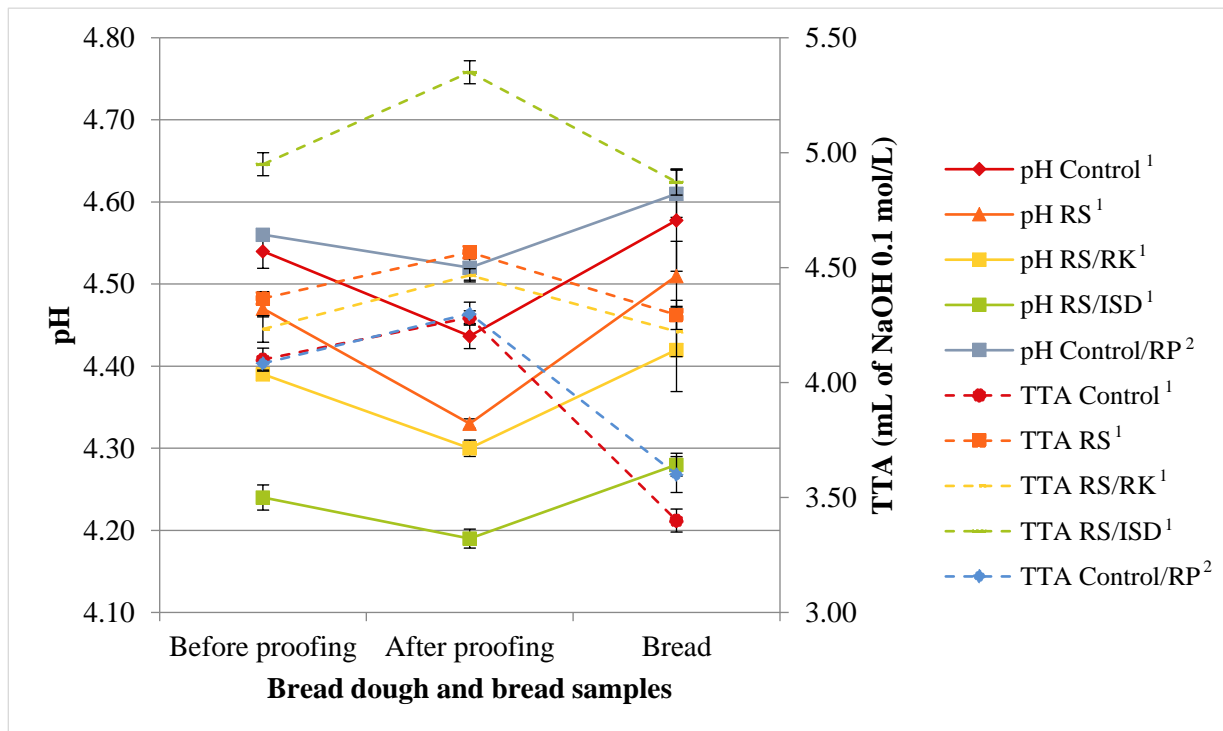


Figure 21 pH and total titratable acidity (TTA) of bread dough samples (before proofing and after proofing) by standard fermentation¹ or retard proofing², and bread samples of GF sweet potato sourdough breads

¹ Standard fermentation = 1 h fermentation at $37\text{ }^{\circ}\text{C}/87\text{ \% RH}$ in the prover; ² Retard proofing = 12 h fermentation at $8\text{ }^{\circ}\text{C}/87\text{ \% RH}$ in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; TTA = total titratable acidity; n = 3 (bread dough samples), n = 9 (bread samples).

The pH of bread doughs before proofing ranged from 4.24 ± 0.01 (RS/ISD) to 4.56 ± 0.01 (Control/RP), and the TTA ranged from 4.08 ± 0.03 mL (Control/RP) to 4.96 ± 0.05 mL (RS/ISD). After proofing, the pH of the bread doughs decreased to between 4.19 ± 0.01 (RS/ISD) to 4.52 ± 0.02 (Control/RP), which are significantly higher than the pH of 3.53 reported for GF rice dough after sourdough-based proofing (Pruska-Kędzior et al., 2008). In this study the TTA increased to between 4.28 ± 0.03 mL (Control) to 5.36 ± 0.05 mL (RS/ISD), which is lower than the TTA of 6.42 mL reported in the study mentioned above.

Bread dough acidity is influenced by the type of flour used for sourdough bread production (Salovaara & Valjakka, 1987). Flour with a higher ash content may increase the buffering capacity of the sourdough, thus enhancing the production of lactic acid and increasing the TTA of the bread dough (Hammes, Stolz & Gänzle, 1996). For example, brown rice sourdough may have higher TTA than white rice sourdough, as the brown rice flour has a higher ash content (1.73 %) than white rice flour (0.98 %) (Puri, Dhillon & Banura, 2014). In addition, flour with low concentrations of fermentable carbohydrates (e.g. glucose and fructose) may limit the growth of LAB, resulting in lower amounts of lactate and acetate being produced during proofing (Gänzle, Ehmann & Hammes, 1998).

The pH of the GF sweet potato sourdough breads increased sharply after baking and concomitant with the decrease of TTA possibly due to volatilisation of organic acids during baking (García-Mantrana, Monedero & Haros, 2015). After baking, the pH of the GF sweet potato sourdough breads ranged from 4.28 ± 0.05 (RS/ISD) to 4.61 ± 0.03 (Control/RP), and the TTA ranged from 3.40 ± 0.05 mL (Control) to 4.87 ± 0.06 mL (RS/ISD). The pH is lower, and the TTA is higher than those reported for rice sourdough breads produced by following fermentation with single strains of *L. reuteri* or *L. brevis* (pH 4.62 - 4.97; TTA 1.5 - 2.6 mL) (Axel et al., 2016). The differences between this study and previous studies may be due to the different microbial composition of the sourdough starter and the interactions between the LAB and yeast (Valmorri et al., 2010).

The RS/ISD bread doughs (before and after proofing) and bread showed significantly ($p < 0.05$) lower pH and higher TTA than the other formulations, which agrees with the results of others who also reported bread doughs had a lower pH and higher TTA following addition of increasing amounts of sourdough (Crowley et al., 2002; Novotni et al., 2012; Różyło et al., 2015).

In this study there was no significant difference ($p > 0.05$) between the TTA of the RS bread (4.29 ± 0.06 mL) and RS/RK bread (4.22 ± 0.11 mL), nor the Control bread (3.40 ± 0.05 mL) or the Control/RP bread (3.60 ± 0.08 mL). However, the TTA of GF sweet potato sourdough breads made using rice syrup (RS, RS/RK, and RS/ISD) were significantly ($p < 0.05$) higher than the GF sweet potato sourdough breads made with coconut sugar (Control and Control/RP), confirming that the type of sugars within the sourdough have a significant effect on the carbohydrate metabolism of LAB and hence the acidification of the sourdough bread (Gobbetti, Corsetti & Rossi, 1994).

4.3.4 Concentration of organic acids

Sourdough acidification is dependent on the composition of the microflora, the amount of fermentable carbohydrates, and fermentation conditions (Katina, 2005; Corsetti & Settanni, 2007; Minervini et al., 2014). Organic acids produced during sourdough fermentation affect the protein and starch components of the dough and their functional properties, thus improving the bread texture (Arendt, Ryan & Dal Bello, 2007). The decrease in pH due to production of organic acids increases the enzymatic activities of the amylases and proteases present in the flour, resulting in reduced bread firmness and delayed bread staling (Fadda et al., 2014). Organic acids produced during sourdough fermentation also affect bread aroma and flavour (Paterson & Piggott, 2006). Acidification also accelerates the activation of yeast invertase, enhancing fructan degradation during sourdough fermentation (Nilsson et al., 1988).

The results of HPLC analysis of the lactic and acetic acid concentrations in the bread doughs before and after proofing as well as bread samples of the GF sweet potato sourdough breads are shown in Figures 22 and 23. Before proofing, the lactic acid concentration of the bread doughs ranged from 0.27 ± 0.00 (RS) to 0.53 ± 0.04 g/100 g (RS/ISD). Whereas the concentration of acetic acid of the bread doughs ranged from 0.23 ± 0.01 (RS) to 0.47 ± 0.01 g/100 g (RS/ISD). Accumulation of lactic and acetic acids have been reported during proofing for all the bread doughs due to LAB metabolism of fermentable sugars present in the bread dough (Gänzle, Vermeulen & Vogel, 2007).

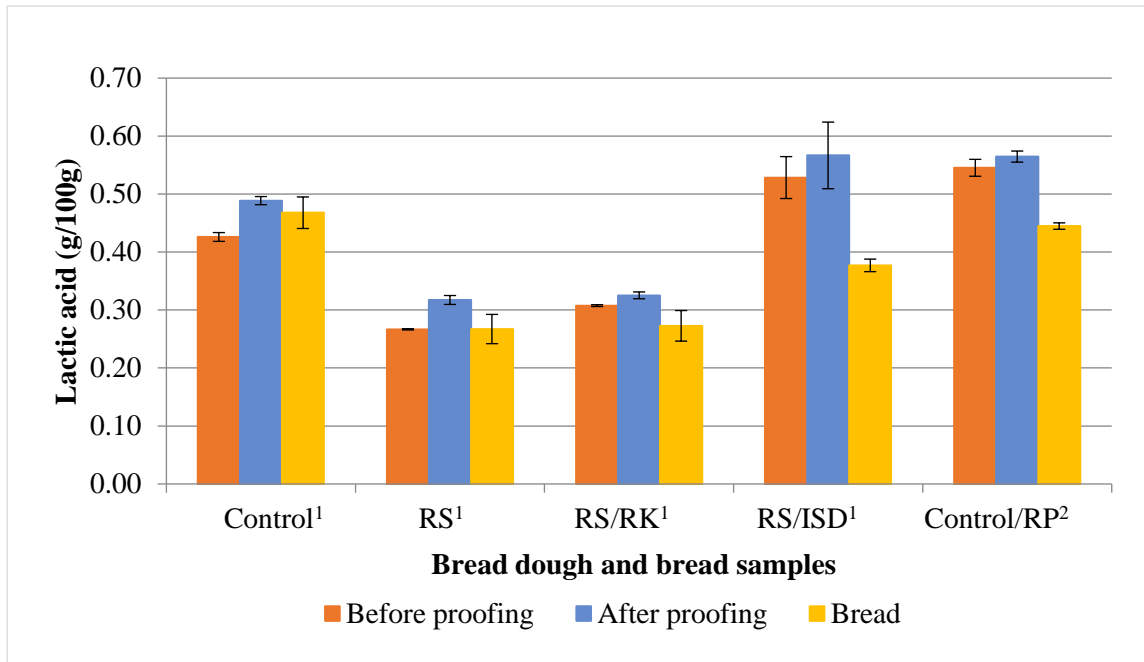


Figure 22 Lactic acid concentration in bread dough samples (before proofing and after proofing) by standard fermentation¹ or retard proofing², and bread samples of GF sweet potato sourdough breads

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 4.

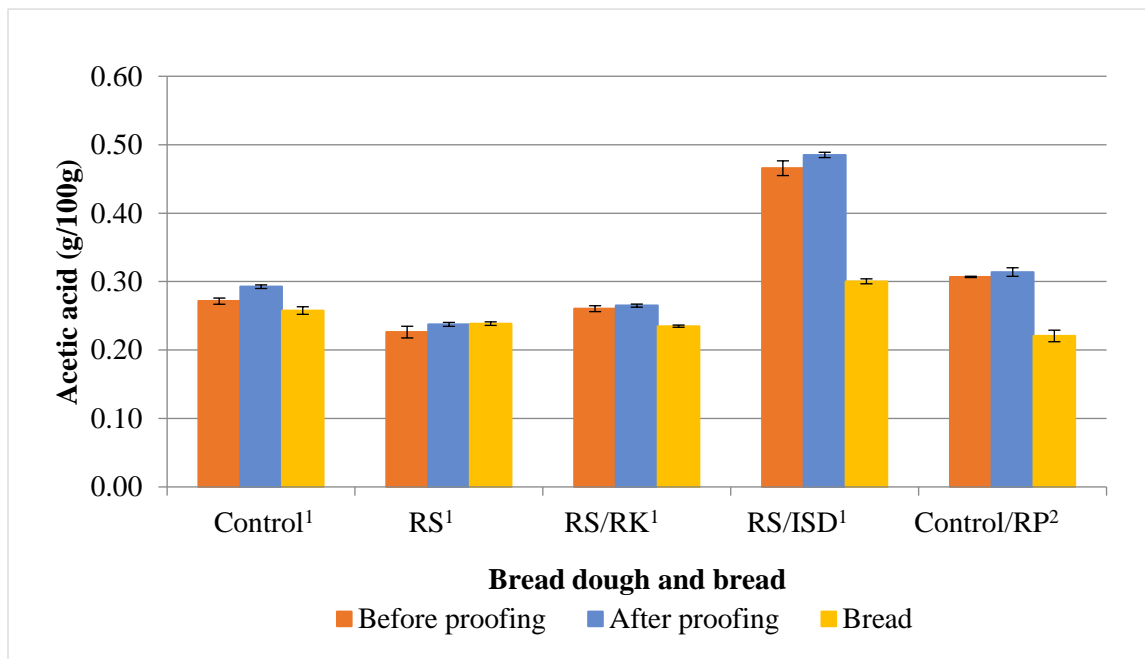


Figure 23 Acetic acid concentration in bread dough samples (before proofing and after proofing) by standard fermentation¹ or retard proofing², and bread samples of GF sweet potato sourdough breads

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 4.

The highest concentrations of both lactic and acetic acids were detected in the RS/ISD bread dough after proofing (0.57 ± 0.06 g/100 g and 0.49 ± 0.00 g/100 g, respectively). Other studies have also reported that the content of lactic and acetic acids in sourdough-fermented bread dough significantly increase following the addition of increasing percentages of sourdough to the formulation (Sanz-Penella, Tamayo-Ramos & Haros, 2012).

The RS and RS/RK bread doughs after proofing contained significantly ($p < 0.05$) lower concentrations of lactic acid (0.32 ± 0.01 g/100 g and 0.33 ± 0.01 g/100 g, respectively) and acetic acid (0.24 ± 0.00 g/100 g and 0.27 ± 0.01 g/100 g, respectively) than the other bread doughs (lactic acid 0.49 - 0.57 g/100 g; acetic acid 0.29 - 0.49 g/100 g). This may be due to the relatively low fructose content in the bread doughs made with rice syrup compared to those made with coconut sugar, as it has been reported that addition of fructose accelerates LAB metabolic activity in sourdough, resulting in a greater production of lactic and acetic acids (Gobbetti, Corsetti & Rossi, 1995).

After baking, the lactic acid concentration of the baked bread samples ranged from 0.27 ± 0.03 g/100 g (RS) to 0.47 ± 0.03 g/100 g (Control), while the acetic acid concentration ranged from 0.22 ± 0.01 g/100g (Control/RP) to 0.30 ± 0.00 g/100 g (RS/ISD). The concentrations of both lactic and acetic acid decreased during baking for all the GF sweet potato sourdough breads. Organic acids produced during sourdough fermentation are volatile, and therefore evaporate during baking at high temperatures (Pétel, Onno & Prost, 2017). The results in this study agree with previous findings that higher amounts of acetic acid are lost during bread baking than lactic acid (Spicher, 1983).

The fermentation quotient (FQ) is the molar ratio between the amount of lactic and acetic acid produced in the sourdough during fermentation, which is strongly associated with the taste, flavour, and microbial stability of the sourdough bread (Gobbetti, 1998; Corsetti & Settanni, 2007). A high content of acetic acid results in a low FQ with a strong acidic flavour development of the bread, whereas a high FQ results from low acetic acid production and a bread which is bland with little flavour (Hansen, 2004). The FQ is influenced by many factors, including fermentable sugars, fermentation temperature and time, and strains of LAB present in the sourdough (Corsetti, 2013). The FQ values of the GF sweet potato sourdough breads, ranged between 1.97 and 4.48 (Table 12). The Control, RS/RK, RS/ISD and Control/RP were characterised by a FQ within the favourable range of 1.5-4 suggested by Spicher (1983) for

development of a preferred aroma profile and structure of the sourdough bread. The RS and RS/RK had relatively higher FQ values indicating the acetic acid concentration in these two samples were low relative to lactic acid, which resulted in a mild acidic taste and aroma of the final breads. These results may be due to the limited available fermentable sugars (e.g. fructose) for acetate production (Salovaara, 1998) in the bread made using rice syrup.

Table 12 Fermentation quotient of GF sweet potato sourdough bread samples made using different formulations and fermentation processes

Parameters	Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Fermentation Quotient	2.97	4.48	3.93	1.97	2.74

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing.

The FQ value of the Control/RP produced by retard proofing at low temperature and the Control produced by short proofing at high temperature were not significantly different. However, the Control/RP resulted in a FQ value (2.74) closer to the optimal FQ range (2.0 - 2.7) recommended for production of superior sourdough bread (Hammes & Gänzle 1998). This finding is supported by the sensory analysis data (Section 4.4.7), where the Control/RP GF sweet potato sourdough bread achieved the highest mean scores for all the sensory parameters tested.

4.3.5 FODMAPs

4.3.5.1 Bread dough samples (before and after proofing)

FODMAP content (including total fructans) of bread doughs (as determined by HPAEC-PAD and enzymatic assay) of the Control and the reformulated GF sweet potato sourdough breads before and after proofing are presented in Tables 13 and 14. Typical chromatograms of FODMAPs in the Control bread dough samples before proofing (BP) and after proofing (AP) are shown in Figures 24 and 25.

Table 13 FODMAP content (monosaccharides and sugar polyols) of GF sweet potato sourdough bread dough samples (before and after proofing) by standard fermentation¹ or retard proofing²

Bread Dough Sample	FODMAPs by HPAEC with PAD (g per 100 g as wet weight)									
	Monosaccharides					Sugar Polyols				
	Fructose		Glucose		Excess fructose		Sorbitol		Mannitol	
	BP	AP	BP	AP	BP	AP	BP	AP	BP	AP
Control ¹	0.171 ± 0.003 ^{B,c}	0.155 ± 0.001 ^{A,d}	0.148 ± 0.004 ^{B,c}	0.126 ± 0.003 ^{A,c}	0.023 ± 0.001 ^{A,b}	0.029 ± 0.002 ^{A,b}	0.004 ± 0.000 ^{A,c}	0.004 ± 0.000 ^{A,d}	0.033 ± 0.000 ^{A,c}	0.033 ± 0.000 ^{A,c}
RS ¹	0.085 ± 0.000 ^{B,b}	0.065 ± 0.001 ^{A,c}	0.131 ± 0.001 ^{A,b}	0.133 ± 0.003 ^{A,d}	0 ^{A,a}	0 ^{A,a}	0.004 ± 0.000 ^{A,b}	0.004 ± 0.000 ^{A,c}	0.024 ± 0.000 ^{A,a}	0.025 ± 0.000 ^{A,a}
RS/RK ¹	0.055 ± 0.003 ^{B,a}	0.039 ± 0.000 ^{A,a}	0.105 ± 0.000 ^{B,a}	0.098 ± 0.000 ^{A,a,b}	0 ^{A,a}	0 ^{A,a}	0.004 ± 0.000 ^{B,b}	0.003 ± 0.000 ^{A,b}	0.025 ± 0.000 ^{A,a}	0.026 ± 0.000 ^{A,a}
RS/ISD ¹	0.054 ± 0.001 ^{B,a}	0.047 ± 0.000 ^{A,b}	0.104 ± 0.002 ^{B,a}	0.093 ± 0.001 ^{A,a}	0 ^{A,a}	0 ^{A,a}	0.002 ± 0.000 ^{A,a}	0.002 ± 0.000 ^{A,a}	0.028 ± 0.000 ^{A,b}	0.029 ± 0.000 ^{B,b}
Control/RP ²	0.188 ± 0.009 ^{B,d}	0.162 ± 0.001 ^{A,e}	0.103 ± 0.001 ^{A,a}	0.104 ± 0.001 ^{A,b}	0.086 ± 0.009 ^{B,c}	0.058 ± 0.000 ^{A,c}	0.003 ± 0.000 ^{A,b}	0.003 ± 0.000 ^{A,b}	0.032 ± 0.000 ^{A,c}	0.034 ± 0.000 ^{A,c}

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; BP = bread dough before proofing; AP = bread dough after proofing; Excess fructose = fructose – glucose; n = 2.

^{A-B} Values in the same row of each subgroup of FODMAPs (Fructose, Glucose, Excess fructose, Sorbitol, Mannitol) with different superscript letters differ significantly (p < 0.05).

^{a-e} Values in the same column with different superscript letters differ significantly (p < 0.05).

Table 14 FODMAP content (GOS, FOS, total fructans) of GF sweet potato sourdough bread dough samples (before and after proofing) by standard fermentation¹ or retard proofing²

Bread Dough Sample	FODMAPs by HPAEC with PAD (g per 100 g as wet weight)								Total Fructans by Enzymatic Assay (g per 100 g as wet weight)	
	GOS				FOS				Total Fructans	
	Raffinose		Stachyose		Nystose		Kestose			
	BP	AP	BP	AP	BP	AP	BP	AP	BP	AP
Control ¹	0.002 ± 0.000 ^{A,c}	0.002 ± 0.000 ^{A,b}	0.012 ± 0.001 ^{A,c}	0.013 ± 0.001 ^{A,c}	0.039 ± 0.002 ^{A,b}	0.036 ± 0.001 ^{A,b}	ND ^{A,a}	ND ^{A,a}	0.1770 ± 0.0063 ^{B,c}	0.1436 ± 0.0010 ^{A,c}
RS ¹	ND ^{A,a}	ND ^{A,a}	0.010 ± 0.000 ^{A,b}	0.012 ± 0.000 ^{B,b}	0.066 ± 0.002 ^{A,e}	0.076 ± 0.001 ^{B,e}	ND ^{A,a}	ND ^{A,a}	0.0622 ± 0.0014 ^{A,a}	0.0561 ± 0.0014 ^{A,a}
RS/RK ¹	ND ^{A,a}	ND ^{A,a}	0.004 ± 0.000 ^{A,a}	0.005 ± 0.000 ^{B,a}	0.045 ± 0.002 ^{A,d}	0.051 ± 0.000 ^{A,c}	ND ^{A,a}	ND ^{A,a}	0.0632 ± 0.0010 ^{A,a}	0.0621 ± 0.0014 ^{A,a}
RS/ISD ¹	ND ^{A,a}	ND ^{A,a}	0.005 ± 0.000 ^{B,a}	0.004 ± 0.000 ^{A,a}	0.055 ± 0.000 ^{B,e}	0.044 ± 0.000 ^{A,d}	ND ^{A,a}	ND ^{A,a}	0.0997 ± 0.0010 ^{B,b}	0.0920 ± 0.0024 ^{A,b}
Control/RP ²	0.001 ± 0.000 ^{B,b}	ND ^{A,a}	0.005 ± 0.000 ^{A,a}	0.005 ± 0.000 ^{A,a}	0.023 ± 0.001 ^{A,a}	0.024 ± 0.000 ^{A,a}	ND ^{A,a}	ND ^{A,a}	0.1685 ± 0.0037 ^{A,c}	0.1652 ± 0.0024 ^{A,d}

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; BP = bread dough before proofing; AP = bread dough after proofing; GOS = galactooligosaccharides; FOS = fructooligosaccharides; Excess fructose = fructose – glucose; ND = not detected; n = 2.

^{A-B} Values in the same row of each subgroup of FODMAPs (Raffinose, Stachyose, Nystose, Kestose, Total Fructans) with different superscript letters differ significantly (p < 0.05).

^{a-e} Values in the same column with different superscript letters differ significantly (p < 0.05).

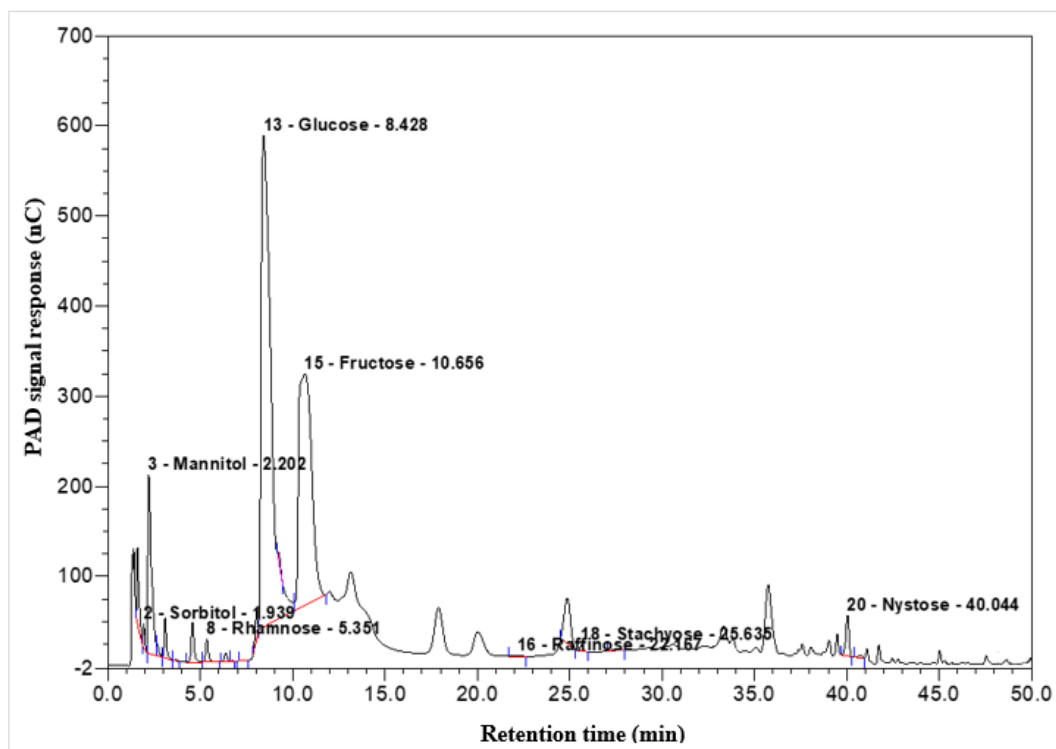


Figure 24 HPAEC-PAD chromatogram profile of FODMAPs in the Control bread dough sample before proofing (BP) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

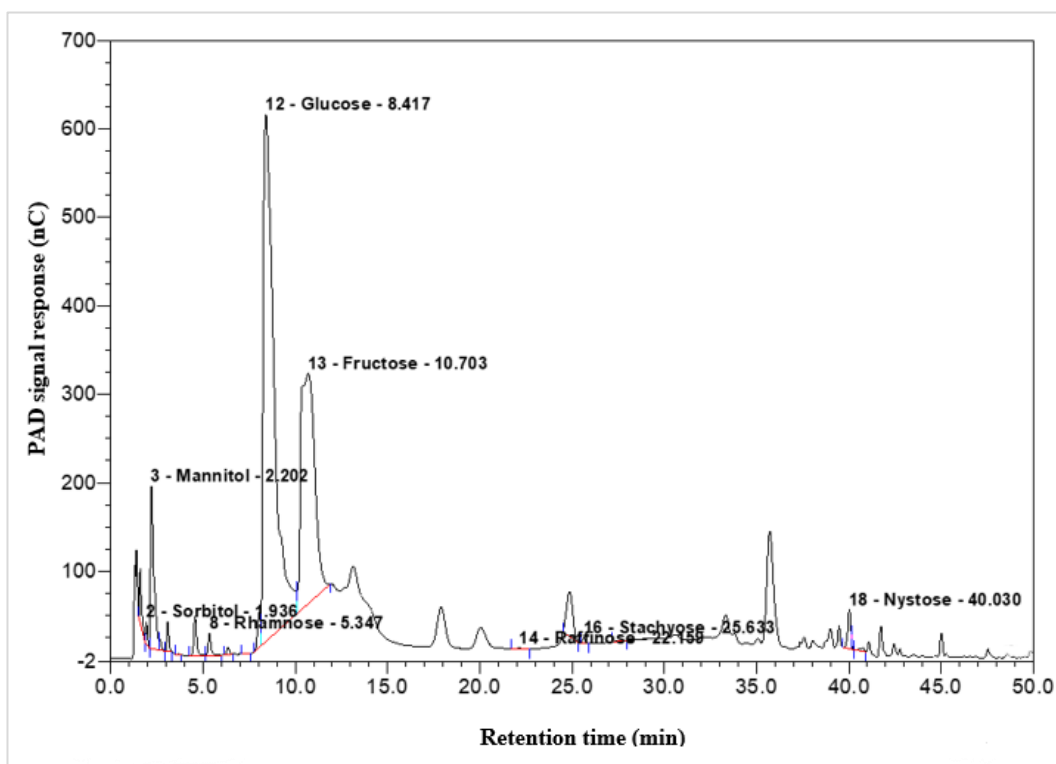


Figure 25 HPAEC-PAD chromatogram profile of FODMAPs in the Control bread dough sample after proofing (AP) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

The fructose concentration in all the GF sweet potato sourdough bread dough samples decreased significantly ($p < 0.05$) during proofing, ranging from 0.054 ± 0.001 g/100 g (RS/ISD) to 0.188 ± 0.009 g/100 g (Control/RP) to 0.039 ± 0.000 g/100 g (RS/RK) to 0.162 ± 0.001 g/100 g (Control/RP). According to Gänzle, Vermeulen and Vogel (2007), this decrease probably corresponds to the metabolism of fructose by heterofermentative LAB through the pentose phosphate pathway, resulting in the increased concentrations of lactic and acetic acids observed during proofing. Fructose can also be metabolised by yeast after being transported across the cell membrane by facilitated diffusion, and subsequently phosphorylated by hexokinase before entering the glycolytic pathway (Entian & Barnett, 1992).

The fructose concentration of bread doughs (before and after proofing) containing coconut sugar (Control and Control/RP) were significantly ($p < 0.05$) higher than in bread doughs made using rice syrup (RS, RS/RK, and RS/ISD). This was expected, as coconut sugar contains 75-80 % sucrose which can be immediately hydrolysed by yeast invertase to produce large amounts of fructose and glucose (Purnomo, 1992; Gobbetti, Corsetti & Rossi, 1994). The Control/RP bread dough after proofing contained the highest amount of fructose (0.162 ± 0.001 g/100 g), and this was significantly ($p < 0.05$) higher than the Control (0.155 ± 0.001 g/100 g), possibly due to inactivation of endogenous LAB and yeast enzymes at the low temperature during prolonged proofing, thereby slowing down the sourdough fermentation (Selomulyo & Zhou, 2007).

Before proofing, the glucose levels of the bread doughs ranged from 0.103 ± 0.001 g/100 g (Control/RP) to 0.148 ± 0.004 g/100 g (Control). After proofing, the amount of glucose in the Control (0.126 ± 0.003 g/100 g), RS/RK (0.098 ± 0.000 g/100 g) and RS/ISD (0.093 ± 0.001 g/100 g) bread doughs were significantly ($p < 0.05$) lower than in the bread doughs before proofing. In contrast, the glucose concentration of the RS and Control/RP bread doughs did not change during proofing. During proofing, glucose is utilised by LAB as an energy source via the glycolytic and pentose phosphate pathways (Von Wright & Axelsson, 2011). The sugar is also metabolised by yeast via the respiratory or fermentative pathways (De Vuyst et al., 2016). The stable concentration of glucose during proofing may have occurred due to the hydrolysis of disaccharides (sucrose or maltose) and starch in flour by indigenous amylases or yeast invertase resulting in the release of glucose. These phenomena can counteract the normal decrease in glucose levels due to LAB and yeast metabolism (Jayaram et al., 2013).

As the fructose concentrations in the Control and Control/RP bread doughs containing coconut sugar were higher than the glucose concentration, fructose in excess of glucose (excess glucose) was found in both bread dough samples (before and after proofing). In contrast, no excess fructose was presented in bread doughs made using rice syrup (RS, RS/RK and RS/ISD). The significant differences ($p < 0.05$) in the fructose content among the bread doughs after proofing confirmed the importance of the bread formulation and fermentation process on the FODMAP levels of the breads (Varney et al., 2017). By optimising the amount of added fructose and glucose within the bread formulation, the presence of excess fructose (which is considered a FODMAP) in the bread product can be prevented (Laurent et al., 2020).

Only very low amounts of sugar polyols (0.029-0.037 g/100 g) were detected in the bread dough samples and these did not change during proofing (Table 13). Higher mannitol concentrations ($p < 0.05$) were observed in bread doughs containing coconut sugar after proofing (Control and Control/RP) than the reformulated breads made with rice syrup (RS, RS/RK, RS/ISD). This may be due to the higher amounts of fructose in the breads made with coconut sugar, which can be utilised as an electron acceptor by heterofermentative LAB to produce mannitol (Gobbetti, 1998).

Only trace amounts of GOS (raffinose and stachyose) were detected in GF sweet potato sourdough bread doughs after proofing, ranging from 0.004 g/100 g (RS/ISD) to 0.015 g/100 g (Control). Raffinose levels in bread dough after proofing did not change for the Control (0.002 ± 0.000 g/100 g), but significantly decreased ($p < 0.05$) to undetectable levels for the Control/RP produced by retard proofing. Similar findings have been reported by others (Ziegler et al., 2016), confirming that prolonged proofing times can be used to effectively reduce GOS in bread due to the activities of yeast invertase (Ziegler et al., 2016) or intracellular enzymes (e.g. α -galactosidase, levansucrase) present in most *Lactobacillus* sp. (Teixeira, McNeill & Gänzle, 2012). Raffinose was not detected in bread doughs containing rice syrup (RS, RS/RK, RS/ISD). The stachyose concentration of the Control bread dough after proofing (0.013 ± 0.001 g/100 g) was significantly higher than the other bread doughs (RS, RS/RK, RS/ISD and Control/RP). These results confirm that the FODMAP content of the final bread can be reduced by optimising the ingredients or their proportions in the initial bread formulation (Ispiryan, Zannini & Arendt, 2020), and also by using prolonged fermentation (Struyf, Verspreet & Courtin, 2018).

The FOS levels (nystose and kestose) of the GF sweet potato sourdough bread doughs after proofing ranged from 0.024 g/100 g (Control/RP) to 0.076 g/100 g (RS), which did not change for most bread doughs (Control, RS/RK and Control/RP). Kestose was not detected in any of the bread doughs. The nystose concentration in RS bread dough significantly increased ($p < 0.05$) from 0.066 ± 0.002 g/100 g to 0.076 ± 0.001 g/100 g during proofing. This is in contrast to previous studies (Verspreet et al., 2013; Struyf et al., 2017; Loponen & Gänzle, 2018), which reported that sourdough LAB (e.g. *L. brevis*, *L. fermentum*, *L. plantarum*) and yeast (e.g. *S. cerevisiae*, *K. marxianus*) have the ability to convert more complex FOS and fructans to fructose and glucose by endocellular or extracellular enzymatic activities (e.g. invertase, inulinase, fructosidase, fructanases), therefore reduced FOS levels are expected after dough proofing. The different results found in the current study may be due to differences in the microbiota composition, or the formulation or fermentation conditions used for bread production. A significant decrease ($p < 0.05$) in nystose levels was found in the RS/ISD bread dough after proofing, from 0.055 ± 0.000 g/100 g to 0.044 ± 0.000 g/100 g, which probably due to the increased carbohydrate metabolic activities of the microbiota resulting from the increased percentage of sourdough starter added.

A reduction in fructan concentrations was observed for all the bread doughs after proofing, with significant reductions ($p < 0.05$) for the Control (18.87 %) and the RS/ISD (7.72 %). Similar findings have been reported from previous studies, where fermentation with the sourdough or yeast alone resulting in a significant reduction of fructans in bread (Andersson et al., 2009; Jasinska-Kuligowska et al., 2013; Fraberger et al., 2018; Loponen & Gänzle, 2018). The total fructans in the bread doughs after proofing ranged from 0.0561 ± 0.0014 g/100 g (RS) to 0.1652 ± 0.0024 g/100 g (Control/RP). Higher concentrations of fructans ($p < 0.05$) were found in bread doughs made using coconut sugar (Control and Control/RP) than bread doughs made with rice syrup (RS, RS/RK and RS/ISD). These results confirm the significance of the ingredients used in bread production on the final fructan levels in the resulting bread products (Ispiryan, Zannini & Arendt, 2020).

4.3.5.2 Bread samples (after baking)

The FODMAP levels of the Control and the reformulated GF sweet potato sourdough bread samples after baking are shown in Table 15. Typical HPAEC-PAD chromatograms of FODMAPs in the Control and the RS bread samples are shown in Figures 26 and 27.

Table 15 FODMAP content of GF sweet potato sourdough bread samples made using different formulations and fermentation processes

Bread Sample	FODMAPs by HPAEC with PAD (g per 100 g as consumed weight)									Total Fructans by Enzymatic Assay (g per 100 g as consumed weight)
	Monosaccharides			Sugar Polyols		GOS		FOS		Total Fructans
	Fructose	Glucose	Excess fructose	Sorbitol	Mannitol	Raffinose	Stachyose	Nystose	Kestose	
Control ¹	0.205 ± 0.000 ^d	0.176 ± 0.004 ^c	0.029 ± 0.004 ^b	0.005 ± 0.000 ^{a,b}	0.040 ± 0.000 ^b	ND	0.012 ± 0.001 ^c	0.046 ± 0.002 ^a	ND	0.1310 ± 0.0033 ^c
RS ¹	0.111 ± 0.001 ^b	0.160 ± 0.001 ^{b,c}	0	0.005 ± 0.000 ^a	0.030 ± 0.000 ^a	ND	0.010 ± 0.000 ^b	0.062 ± 0.000 ^c	ND	0.0657 ± 0.0061 ^a
RS/RK ¹	0.082 ± 0.003 ^a	0.153 ± 0.009 ^b	0	0.006 ± 0.000 ^b	0.030 ± 0.000 ^a	ND	0.006 ± 0.000 ^a	0.053 ± 0.000 ^b	ND	0.0687 ± 0.0033 ^a
RS/ISD ¹	0.089 ± 0.002 ^a	0.135 ± 0.001 ^a	0	0.005 ± 0.000 ^a	0.032 ± 0.001 ^a	ND	0.007 ± 0.000 ^a	0.055 ± 0.000 ^b	ND	0.0779 ± 0.0000 ^a
Control/RP ²	0.179 ± 0.003 ^c	0.158 ± 0.000 ^b	0.021 ± 0.003 ^b	0.005 ± 0.000 ^a	0.040 ± 0.001 ^b	ND	0.010 ± 0.000 ^b	0.044 ± 0.001 ^a	ND	0.1010 ± 0.0032 ^b

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; GOS = galactooligosaccharides; FOS = fructooligosaccharides; Excess fructose = fructose – glucose; ND = not detected; n = 2.

^{a-c}Values in the same column with different superscript letters differ significantly (p < 0.05).

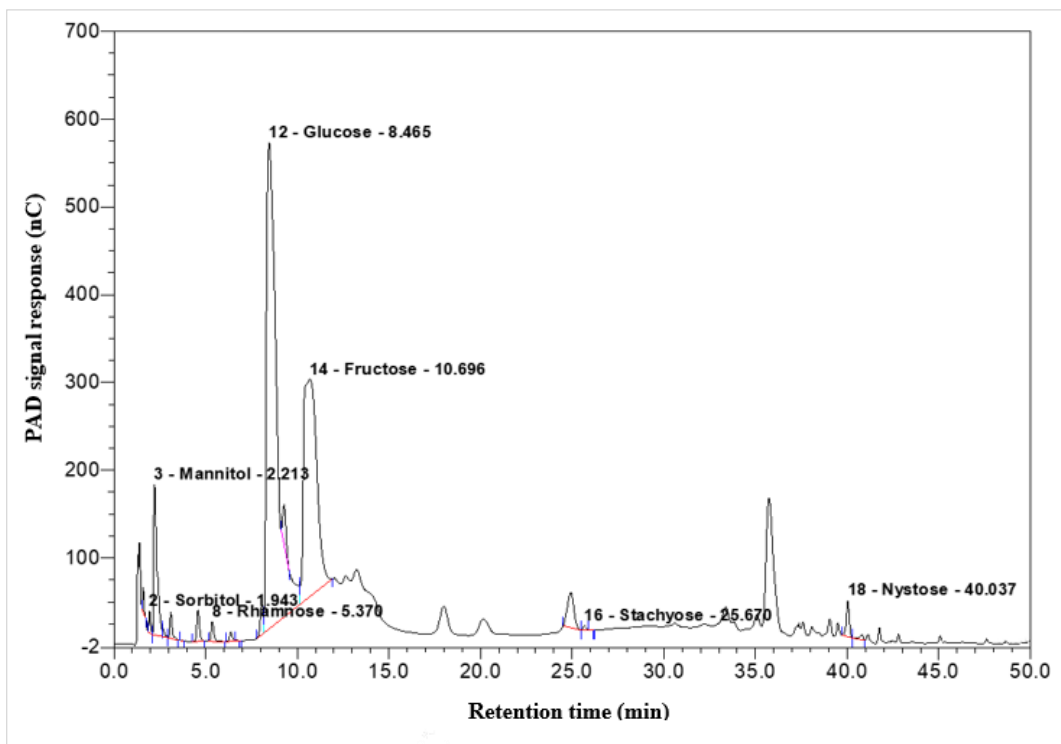


Figure 26 HPAEC-PAD chromatogram profile of FODMAPs in the Control bread sample (GF sweet potato sourdough bread with coconut sugar) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

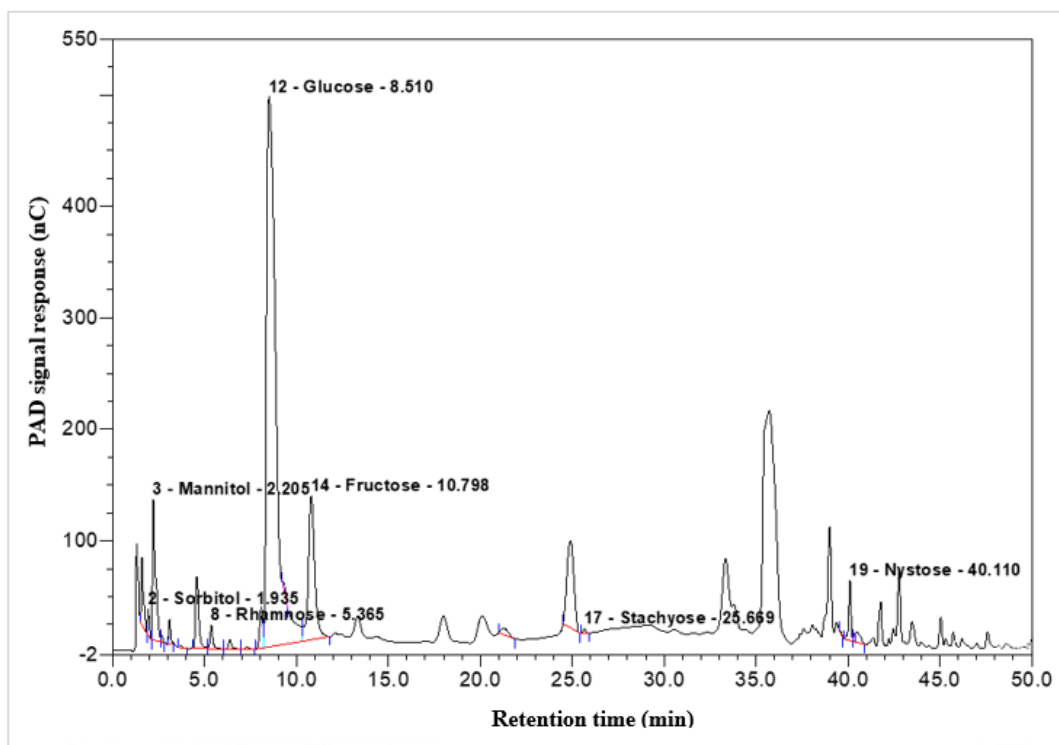


Figure 27 HPAEC-PAD chromatogram profile of FODMAPs in the RS bread sample (GF sweet potato sourdough bread with rice syrup) separated using a Dionex CarboPac PA20 column

Peaks are numbered in order of elution, followed by the corresponding compounds and retention times; only FODMAP sugars are illustrated in the figure, other peaks were not identified.

The fructose concentration in the Control and the reformulated GF sweet potato sourdough breads ranged from 0.082 ± 0.003 g/100 g (RS/RK) to 0.205 ± 0.000 g/100 g (Control), which are lower than commercial Australian white wheat bread (0.26 g/100 g) and GF white breads (0.46 g/100 g) (Biesiekierski et al., 2011). A number of studies have shown that the fructose remaining in the final bread after baking is dependent on the initial ingredients, dough fermentation method, and fermentation time (Ziegler et al., 2016; Longin et al., 2020; Ispiryan, Zannini & Arendt, 2020). The Control and Control/RP breads made using coconut sugar had significantly ($p < 0.05$) higher fructose levels than the breads produced using rice syrup (RS, RS/RK, and RS/ISD), confirming that the fructose levels of bread is impacted by the type of sugar used in the formulation.

The glucose content of the bread samples ranged from 0.135 ± 0.001 g/100 g (RS/ISD) to 0.176 ± 0.004 g/100 g (Control), which is similar to that reported for five commercial Irish breads (0.10-0.23 g/100 g) (Ispiryan, Zannini & Arendt, 2020). As the fructose content of the RS, RS/RK, and RS/ISD breads were lower than the glucose content, no excess fructose was detected in these breads. In contrast, the fructose in the Control and the Control/RP was higher than the glucose, resulting in excess fructose in these two breads (0.029 ± 0.004 g/100 g and 0.021 ± 0.003 g/100 g, respectively). However, these levels are significantly lower than the excess fructose in Australian GF white bread (0.24 g/100 g) (Biesiekierski et al., 2011), but higher than in Irish GF white bread (not detected, detection limit = 0.005 g/100 g DM) (Ispiryan, Zannini & Arendt, 2020), suggesting variations in flour and ingredients, or different production processing parameters may lead to a different FODMAP content in the final bread products.

The sugar polyol (sorbitol and mannitol) concentrations of the Control (0.045 g/100 g) and Control/RP (0.045 g/100 g) breads were higher than the RS (0.035 g/100 g), RS/RK (0.036 g/100 g) and RS/ISD (0.037 g/100 g) breads. According to previous studies (Biesiekierski et al., 2011; Ispiryan, Zannini & Arendt, 2020), only trace or nondetectable amounts of sugar polyols are present in most commercial Australian and Irish bread products (12 of 15), except for wheat sourdough (0.21 g/100 g), rye sourdough (0.16 g/100 g), and GF white breads (0.03 g/100 g). The sugar polyol content of the GF sweet potato sourdough breads in this study were significantly lower than that reported for wheat and rye sourdough breads, but similar to that of the GF white bread. Some heterofermentative LAB can convert the fructose released from the hydrolysis of sucrose or fructan to mannitol using the enzyme mannitol-dehydrogenase, thus the amount of mannitol in sourdough bread may be increased during sourdough

fermentation (Gänzle, Vermeulen & Vogel, 2007; Menezes et al., 2019). Reducing the amount of kumara flour (potentially high in mannitol) in the RS/RK formulation (from 2.81 % to 1.50 %) did not result in any reduction in mannitol content compared to the RS formulation. This was probably due to the presence of trace amounts of mannitol in the bread samples, as well as the lower percentage of kumara flour used compared to the other ingredients.

No raffinose or kestose were detected in any of the bread samples. The stachyose levels ranged from 0.006 ± 0.000 g/100 g (RS/RK) to 0.012 ± 0.001 g/100 g (Control), whereas the nystose levels ranged from 0.044 ± 0.001 g/100 g (Control/RP) to 0.062 ± 0.000 g/100 g (RS). The results are in line with previously reported values (Ispiryan, Zannini & Arendt, 2020). In most wheat and GF bread products, GOS and FOS levels are only present in very low amounts, however breads made using rye, spelt, wholemeal, wholegrain and multigrain or seeds may contain higher amounts of raffinose, stachyose and nystose (Biesiekierski et al., 2011; Varney et al., 2017).

The total fructans in the GF sweet potato sourdough breads made in this study ranged from 0.0657 ± 0.0061 g/100 g (RS) to 0.1310 ± 0.0033 g/100 g (Control), which are lower than those reported for 10 commercial Australian breads (0.14-1.42 g/100 g, 0.19 g/100 g for GF white bread) (Biesiekierski et al., 2011) and 5 GF UK breads (0.36-1.79 g/100 g) (Whelan et al., 2011). GF breads are generally low in fructans, and sourdough LAB are capable of cleaving and converting large amounts of fructans to sucrose and fructose (Loponen & Gänzle, 2018; Ispiryan, Zannini & Arendt, 2020). High fructan degradation has been observed in sourdoughs containing LAB and yeast, as the acidic environment produced by LAB metabolism may improve the fructan hydrolysing activity of yeast invertase (Nilsson, Öste & Jägerstad, 1987).

Reformulated GF sweet potato sourdough breads containing rice syrup (RS, RS/RK, RS/ISD) instead of coconut sugar (Control and Control/RP) resulted in bread samples with significantly ($p < 0.05$) reduced total fructan content, which indicates the importance of the sugar type used in bread-making for determining the FODMAP levels of breads. The Control/RP produced by retard proofing (12 h at 8 °C/87 % RH) had significantly lower ($p < 0.05$) total fructans than the Control made using the same formulation but shorter proofing time (1 h at 37 °C/87 % RH), which is consistent with previous findings (Ziegler et al., 2016; Fraberger et al., 2018). Prolonged yeast fermentation (4.5 h) and sourdough fermentation using a longer incubation time (72 h) significantly reduced the amount of fructans in breads as the prolonged fermentation

time increased the enzymatic activities of the sourdough microbiota and the period available for the metabolism of the dough components (Gänzle, 2014; Ziegler et al., 2016; Fraberger et al., 2018; Gobetti et al., 2019).

4.3.5.3 Total FODMAPs in bread dough and bread samples

The total FODMAPs in bread dough (before and after proofing) and bread samples of the Control and the reformulated GF sweet potato sourdough breads (g per 100 g) compared with the cut-off value of total FODMAPs defined as low in FODMAPs (0.50 g per serve) (Varney et al., 2017) are shown in Figure 28.

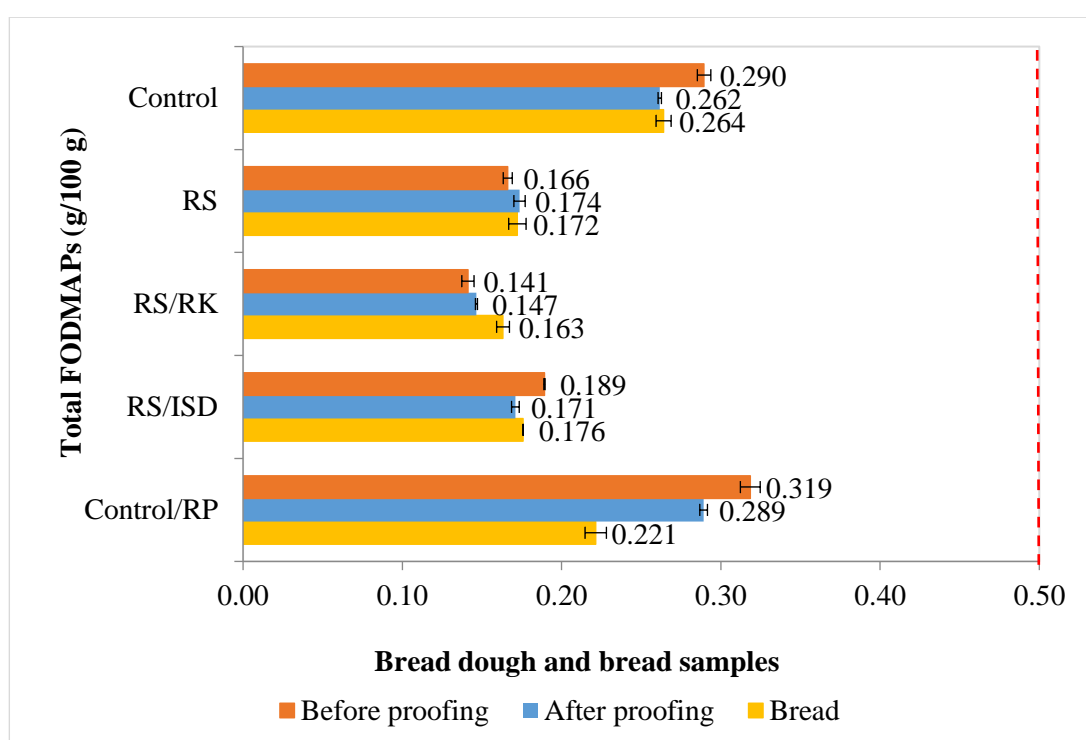


Figure 28 Total FODMAPs in bread dough samples (before proofing and after proofing) by standard fermentation¹ or retard proofing², and bread samples of GF sweet potato sourdough breads

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 2; Vertical red dotted lines = the cut-off level (g per serving) of total FODMAPs defined as low in FODMAP (0.50 g).

Utilisation of low FODMAP ingredients (i.e. replacing coconut sugar with rice syrup) and retard proofing had a significant impact on reducing the FODMAP content of the GF sweet potato sourdough breads. In contrast, reformulating with a reduced amount of high FODMAP constituents (reducing kumara flour from 2.81 % to 1.50 %) and increasing the amount of sourdough starter added (from 24.31 % to 35.00 %) had negligible effects on reducing the total FODMAPs. The total FODMAPs in the GF sweet potato sourdough breads made in this study ranged from 0.163 g/100 g (RS/RK) to 0.264 g/100 g (Control), which are well below the recommended cut-off values and can therefore be considered as low FODMAP bread products, which are less likely to trigger GI symptoms if consumed by sufferers of GI-related diseases such as celiac disease, NCGS and IBS (Muir et al., 2019).

4.3.6 Summary of Phase 4

Phase 4 of this study indicated that different formulations and fermentation processes resulted in variable microbiological and physico-chemical characteristics, as well as FODMAP content of bread dough and bread samples of GF sweet potato sourdough breads. The numbers of LAB and yeast in all the GF sweet potato sourdough bread doughs increased significantly ($p < 0.05$) during proofing. The LAB cell density in RS/ISD bread dough were significantly ($p < 0.05$) higher than the other bread doughs as the percentage of sourdough starter added was increased. The LAB counts of Control/RP bread dough produced by retard proofing (12 h at 8 °C/87 % RH) did not differ ($p > 0.05$) from the other bread doughs produced by standard fermentation (1 h at 37 °C/87 % RH), indicating that retard proofing did not affect the growth of LAB.

Sourdough fermentation significantly ($p < 0.05$) decreased pH and increased TTA in all the bread dough samples after proofing. After baking, volatilisation of organic acids may explain the increased pH and decreased TTA in all GF sweet potato sourdough breads. Increased sourdough addition resulted in significantly ($p < 0.05$) lower pH and higher TTA of RS/ISD bread dough and bread samples. GF sweet potato sourdough breads made with rice syrup (RS, RS/RL and RS/ISD) had significantly ($p < 0.05$) higher TTA than the Control and Control/RP breads made with coconut sugar, indicating the type of sugars may affect the carbohydrate metabolism of LAB and hence acidification of the sourdough bread.

The concentration of lactic and acetic acids increased during proofing for all the bread dough samples but decreased after baking due to evaporation of volatile organic acids. However,

RS/ISD bread dough made with an increased percentage of sourdough starter had the highest concentrations of lactic and acetic acid. GF sweet potato sourdough breads reformulated with rice syrup (RS and RS/RK) had significantly ($p < 0.05$) lower concentrations of lactic and acetic acids in the bread doughs compared to those made with coconut sugar (Control and Control/RP), most likely due to a reduction of the fermentable substrate fructose. Higher FQ values were obtained for the RS and RS/RK bread doughs made with rice syrup, indicating that lower levels of acetic acid were produced than lactic acid resulting in a mild acidic flavour of the breads. Control/RP bread dough with retard proofing had a FQ closer to the optimum FQ for superior sourdough bread, which correlated to the highest mean scores for all the sensory attributes in Phase 5 of this study.

Fructose and glucose in all the bread dough samples were significantly ($p < 0.05$) decreased after proofing. Reduction of fructans were also observed in all the bread dough samples after proofing. Only trace amounts of sugar polyols (sorbitol and mannitol), GOS (raffinose and stachyose) and FOS (nystose) were detected in the bread dough and bread samples. No kestose was detected in any bread dough or bread sample. Reformulation of the GF sweet potato sourdough breads with rice syrup significantly ($p < 0.05$) reduced the amounts of excess fructose, mannitol and total fructans in the bread dough and bread samples. Control/RP produced by retard proofing also showed significantly ($p < 0.05$) lower total fructans than the Control bread. The results showed the potential of using low FODMAP ingredients and retard proofing on reducing the FODMAP levels in GF sweet potato sourdough bread. However, reducing kumara flour and increasing added sourdough starter had negligible effects on reducing the total FODMAPs of GF sweet potato sourdough bread. All GF sweet potato sourdough breads developed in this study could be classified as low in FODMAPs: ranging from 0.163 to 0.264 g/100 g, which are well below the recommended low FODMAP criteria (0.50 g per serve).

4.4 Characterisation of the Control and the Reformulated GF Sweet Potato Sourdough Breads

4.4.1 Introduction

In Phase 5, the overall characteristics (loaf volume, water activity, texture, colour, microbial shelf life) of the Control and the reformulated GF sweet potato sourdough breads were analysed. The consumer acceptability of the Control and the reformulated GF sweet potato sourdough breads were determined by sensory evaluation of the breads. The effects of different formulations and fermentation processes on the baking characteristics and sensory properties of GF sweet potato sourdough breads were analysed (Section 3.5).

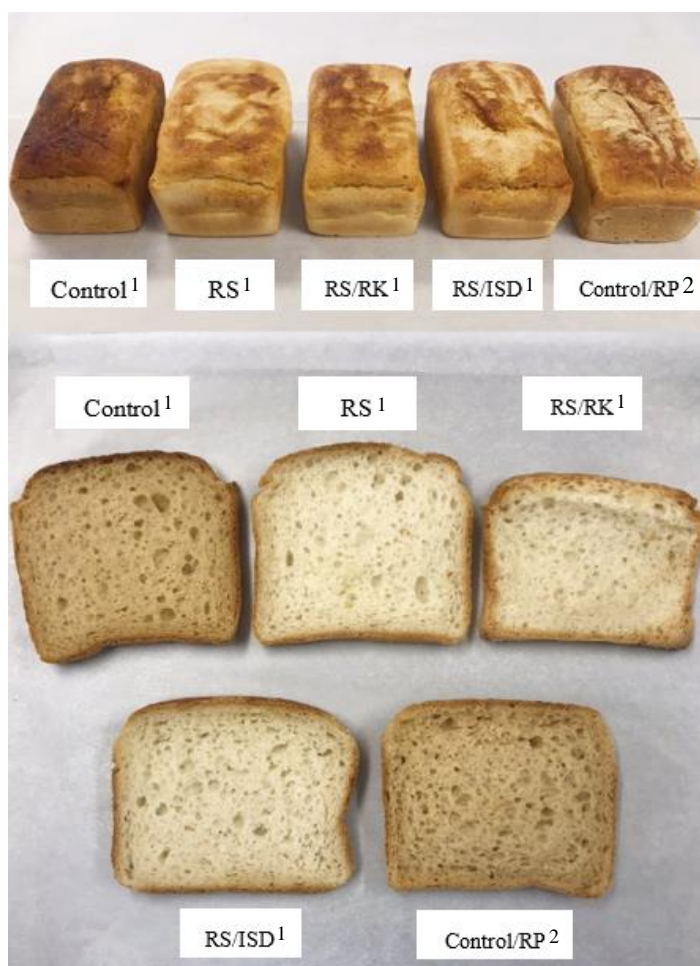


Figure 29 Whole loaves and cross sections of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing.

Significant differences ($p < 0.05$) were found in loaf volume, baking weight loss, water activity, textural characteristics, colour and sensory properties of the bread samples, potentially due to the variations in ingredients and fermentation processes. Figure 29 shows images of whole loaves and cross section of the Control and the reformulated GF sweet potato sourdough breads and differences in loaf volume and crumb/crust colour.

4.4.2 Bread volume

Loaf volume is the most important quality characteristic of bread, as this can be visually observed by the consumer and impacts the overall acceptability of the product (Arendt et al., 2008). The mean values of loaf weight, loaf volume and specific volume of GF sweet potato sourdough breads made using different formulations and fermentation processes are shown in Table 16.

Table 16 Loaf weight, loaf volume and specific volume of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Parameters	Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Loaf weight (g)	534.67 ± 1.15 ^b	538.67 ± 3.06 ^b	525.67 ± 0.58 ^a	534.33 ± 2.08 ^b	565.00 ± 1.73 ^c
Loaf volume (cm ³)	1236.67 ± 5.77 ^b	1313.33 ± 5.77 ^c	1175.00 ± 5.00 ^a	1326.67 ± 5.77 ^c	1241.67 ± 7.64 ^b
Specific volume (cm ³ /g)	2.31 ± 0.01 ^c	2.44 ± 0.02 ^d	2.24 ± 0.01 ^b	2.48 ± 0.00 ^e	2.20 ± 0.01 ^a

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 3. ^{a-e}Values in the same row with different superscript letters are significantly different ($p < 0.05$).

The loaf volume of the breads ranged from 1175.00 ± 5.00 cm³ (RS/RK) to 1326.67 ± 5.77 cm³ (RS/ISD). The loaf volume of the Control bread (1236.67 ± 5.77 cm³) was different ($p < 0.05$) from RS (1313.33 ± 5.77 cm³), RS/RK (1175.00 ± 5.00 cm³), and RS/ISD (1326.67 ± 5.77 cm³), but not different from the Control/RP (1241.67 ± 7.64 cm³). These results indicate that the loaf volume of the bread is dependent of the dough formulation as has been previously reported (Różyło, Le Bail & Coucoux, 2000).

GF rice breads exhibited low volume due to the absence of gluten which is essential for retaining gas to obtain the desired volume (Demirkesen et al., 2010). The addition of resistant

starch (such as tapioca starch, Hi-Maize starch, and potato starch) also impacts on bread volume (Korus et al., 2009). Resistant starch has fine particle sizes, low water-binding capacity which cannot be gelatinised, hence it can retain its form and has little effect on the structural properties of the batter during bread-making (Tsatsaragkou, Gounaropoulos, & Mandala, 2014). As the GF bread texture is strongly associated with starch gelatinisation, it is less prone to pasting, which negatively impacts the expansion of the cell structure and produces a denser crumb with lower loaf volume (Miyazaki et al., 2006).

The specific volumes of all the baked GF sweet potato sourdough breads were significantly different ($p < 0.05$) from each other, ranging from 2.20 ± 0.01 (Control/RP) to 2.48 ± 0.00 cm^3/g (RS/ISD). The results are higher than the specific volumes of 1.50 to 1.89 cm^3/g reported by Renzetti and Arendt (2009) for GF brown rice yeast bread and breads with protease treatments, suggesting the beneficial effects of sourdough fermentation and the addition of hydrocolloids and emulsifier on the specific volume of the GF breads in this study.

The addition of sourdough into the GF formulation has been reported to increase the specific volume by 19.5% compared to GF yeast bread (Cappa et al., 2016). The positive effects on volume are thought to be due to modification of the rheological characteristics of the dough by metabolites produced by LAB during fermentation, which improve the deformation and gas holding capability of the doughs (Gobbetti et al., 2005).

Hydrocolloids such as xanthan, locust and arabic bean gum, carrageenan and guar gums, and cellulose derivatives (Rosell, Rojas & De Barber, 2001; Guarda et al., 2004), and emulsifiers such as lecithin, diacetyl tartaric esters of monoglycerides (DATEM), ethoxylated monoglycerides (EMG), calcium- and sodium stearyl lactylate (CSL and SSL) (Stampfli & Nersten, 1995) are high water-binding macromolecules that can synergistically create bonds within the flour protein network and retain more gas during mixing and proofing. The addition of hydrocolloids and emulsifiers within the GF sweet potato sourdough bread formulation noticeably improved the mixing and handling performance of the dough, thus producing breads with higher volumes, better porosity and softer texture (Demirkesen et al., 2014).

The RS/ISD bread made with increased sourdough addition showed the highest specific volume (2.48 ± 0.00 cm^3/g), whereas the Control/RP made by retard proofing at refrigerated temperature had the lowest specific volume (2.20 ± 0.01 cm^3/g). Similar increases in specific

volume of the loaf with increased added sourdough have also been reported (Jitrakbumrung & Therdthai, 2014), as sourdough acidification improves the gas holding capacity of the bread dough. Increased CO₂ production was also reported by Sandra et al. (2012) following the addition of sourdough, indicating greater fermentative capacity of yeast in the presence of sourdough LAB (Gobbetti et al., 1995). However, the proofing temperature is the most important parameter to control the growth of sourdough microorganisms (Brandt, Hammes & Gänzle, 2004). Retard-proofing the dough might have affected the growth of LAB and yeasts, consequently producing a weaker dough with smaller volume (Therdthai, Zhou & Adamczak, 2002).

4.4.3 Baking weight loss

Baking weight loss or reduction of moisture content during baking is another important characteristic of baked products (Mondal & Datta, 2008). In this study, different formulations and fermentation processes led to different effects on baking weight loss of the GF sweet potato sourdough breads as shown in Table 17.

Table 17 Baking weight loss of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Parameters	Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Baking weight loss (%)	13.76 ± 0.19 ^b	13.12 ± 0.49 ^b	15.22 ± 0.09 ^c	13.82 ± 0.34 ^b	8.87 ± 0.28 ^a

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 3. ^{a-c}Values in the same row with different superscript letters are significantly different (p < 0.05).

The RS/RK bread showed higher (p < 0.05) levels of moisture loss (15.22 ± 0.09 %) after baking compared to the RS/ISD bread (13.82 ± 0.34 %) and RS bread (13.12 ± 0.49 %). This agrees with previous findings, where the baking weight loss of wheat bread (Kotoki & Deka, 2010) and GF bread (Kim, Yun & Jeong, 2015) both decreased as the percentage of potato flour in the formulation increased. The beneficial effects of potato and sweet potato flours on reduction of moisture loss of bread is ascribed to the high viscosity, water binding capacity and swelling power of high molecular weight amylase and phosphate groups esterified to the amylopectin of the potato starches (Craig et al., 1989).

4.4.4 Water activity

Water activity has a strong effect on microbial growth and bread staling, making it an important quality parameter that reflects on the shelf-life of bread products (Ayub, Wahab & Durrani, 2003). The results of water activity (A_w) of all the fresh made GF sweet potato sourdough breads (Day 0) and at 7 days of storage (Day 7) are shown in Table 18. No significant differences in water activity were found between the control bread (0.9781 ± 0.0025) and other breads (0.9787 ± 0.0031 to 0.9817 ± 0.0010) on Day 0. This result agrees with Lazaridou et al. (2007) who reported an A_w of 0.794 to 0.986 of GF crumbs made with various hydrocolloids added.

Table 18 Water activity (Day 0 and Day 7) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Parameters		Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Water Activity	Day 0	0.9781 ± 0.0025^a	0.9790 ± 0.0017^a	0.9810 ± 0.0007^a	0.9817 ± 0.0010^a	0.9787 ± 0.0031^a
	Day 7	0.9739 ± 0.0040^a	$0.9795 \pm 0.0016^{b,c}$	0.9841 ± 0.0005^c	$0.9811 \pm 0.0008^{b,c}$	$0.9772 \pm 0.0008^{a,b}$

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 3. ^{a-c}Values in the same row with different superscript letters are significantly different ($p < 0.05$).

Results showed significant differences ($p < 0.05$) in the water activities of GF sweet potato sourdough breads with different formulations and fermentation processes at 7 days of storage, with A_w ranging from 0.9739 ± 0.0040 (Control) to 0.9841 ± 0.0005 (RS/RK). The changes in water activity of the crumb during storage varied among the breads. The A_w of the Control, RS/ISD and Control/RP breads decreased ($p < 0.05$), whereas the A_w of the RS and RS/RK breads increased upon storage. According to Lazaridou et al. (2006), a decrease in water activity is associated with moisture loss during storage. However, an increase in water activity of bread during storage was reported by Rosell, Rojas and De Barber (2001), and this was attributed to the higher moisture retention capacity of the hydrocolloids as well as absorption of moisture from the atmosphere.

All the GF sweet potato sourdough breads were visually checked for microbial or mould growth after opening the modified atmosphere packaging on Day 0. GF formulations commonly

include hydrocolloids with thickening properties that increase the water binding capacity of the crumb which may retard moisture loss and staling of bread (Anton & Artfield, 2008; Sciarini et al., 2010). However, higher water activity and moisture content have been linked with a tendency for microbial spoilage. No mould growth was visually observed during the first week of storage for any of the bread samples, which may be due to the preservative effects of organic acids, bacteriocins and anti-microbial substances produced during sourdough fermentation by sourdough LAB (Arendt, Dal Bello & Ryan, 2009; Messens & De Vuyst, 2002). Similar observations have been reported in previous studies, where addition of sourdough fermented by specific antifungal strains such as *L. plantarum* FST 1.7 and *L. amylovorus* DSM 19280, inhibited the growth of bread spoilage fungi (*Fusarium culmorum*, *Penicillium expansum*, *Penicillium roqueforti*, and *Aspergillus niger*) and extended the shelf life of GF breads (Moore, Dal Bello & Arendt, 2008; Ryan et al., 2011; Axel et al., 2015).

4.4.5 Crumb texture

Crumb texture is considered one of the most important quality parameters of bread that can be perceived by consumers through the senses of touch and taste and is a decisive criterion of the overall acceptability of the product (Lassoued et al., 2007). A group of physical characteristics including hardness, springiness, cohesiveness, gumminess, chewiness, and resilience is measured by instrumental texture profile analysis (TPA) that mimics the deformation and disintegration of the bread during mastication (Bourne, 2002). The positive impact of sourdough fermentation on improving the textural properties of breads are the subject of numerous reviews (Katina, 2005; Arendt, Ryan & Dal Bello, 2007; Arendt & Moroni, 2013; Galle, 2013). The textural characteristics of all the GF sweet potato sourdough bread samples are shown in Table 19.

Table 19 Textural parameters of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Parameters	Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Hardness (N)	16.30 ± 2.83 ^{b,c}	14.17 ± 2.26 ^{a,b}	17.16 ± 2.74 ^c	16.69 ± 1.28 ^{b,c}	12.89 ± 1.54 ^a
Springiness	0.95 ± 0.02 ^b	0.96 ± 0.01 ^b	0.94 ± 0.01 ^b	0.91 ± 0.01 ^a	0.95 ± 0.01 ^b
Cohesiveness	0.56 ± 0.04 ^{a,b}	0.58 ± 0.05 ^{a,b}	0.60 ± 0.05 ^b	0.53 ± 0.03 ^a	0.66 ± 0.06 ^c
Gumminess	9.12 ± 1.42 ^{a,b}	8.16 ± 0.76 ^a	10.23 ± 1.19 ^b	8.83 ± 0.43 ^a	8.50 ± 0.80 ^a
Chewiness (N)	8.66 ± 1.38 ^{a,b}	7.81 ± 0.75 ^a	9.67 ± 1.14 ^b	8.04 ± 0.35 ^a	8.06 ± 0.77 ^a
Resilience	0.24 ± 0.03 ^b	0.26 ± 0.03 ^b	0.26 ± 0.02 ^b	0.18 ± 0.02 ^a	0.30 ± 0.03 ^c

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; N = Newton; n = 12. ^{a-c}Values in the same row with different superscript letters are significantly different (p < 0.05).

Differences in the crumb textural parameters (hardness, springiness, cohesiveness, gumminess, chewiness and resilience) indicated that the bread formulation and fermentation process had significant effects (p < 0.05) on the crumb texture. The texture of GF breads is influenced by flour composition (Gambus et al., 2001), additives to the formulations (Lazaridou et al., 2007) and also processing parameters (Brites et al., 2008).

4.4.5.1 Hardness

Crumb hardness or firmness is the force required to completely compress the bread sample, which is related to the moisture content, textural cell structure and pore size of the bread (Ozola, Straumite & Klava, 2011). The hardness of the GF sweet potato sourdough bread crumbs ranged from 12.89 ± 1.54 N (Control/RP) to 16.30 ± 2.83 N (Control), which are similar to those of commercial GF breads (10.33 to 20.50 N) (Matos & Rosell, 2012).

Addition of increasing percentages of sourdough in RS/ISD bread resulted in a substantial increase in crumb hardness (16.69 ± 1.28 N) compared with RS bread (14.17 ± 2.26 N). This may be attributed to the fact that this addition impaired CO₂ retention due to the degradation of protein and starch during sourdough fermentation (Barber et al., 1992). The crumb hardness of Control/RP bread (12.89 ± 1.54 N) was probably reduced by retard proofing, which significantly ($p < 0.05$) reduced the firmness compared to the Control bread (16.30 ± 2.83 N). The reduced hardness of the bread produced by retard proofing may be related to low moisture loss in the crumb structure during proofing at cold temperatures as mentioned previously.

4.4.5.2 Springiness

Springiness is the recovery of elasticity that occurs after removal of compression force (Singh et al., 2014). Slight differences were observed between the springiness of GF sweet potato sourdough breads made using different formulations and fermentation processes, which ranged from 0.91 ± 0.01 (RS/ISD) to 0.96 ± 0.01 (RS). The results are higher than most of the springiness data reported for 11 conventional GF breads, which ranged from 0.76 to 1.00 (Matos & Rosell, 2012). High springiness for baked bread is indicative of increased aeration and a springy crumb texture, thus reflecting high elasticity and freshness of the bread (Torres et al., 2013).

Low springiness is associated with brittleness, resulting in the bread being very dry and crumbly (Kadan et al., 2001). As the addition of sourdough increased from 24.31 % to 35.00 %, the springiness of the GF sweet potato sourdough bread decreased significantly ($p < 0.05$) from 0.96 ± 0.01 to 0.91 ± 0.01 , probably due to the high sourdough inhibition of CO₂ production by yeast during sourdough fermentation, resulting in a fragile crumb structure with lower aeration (Różyło et al., 2015).

4.4.5.3 Cohesiveness

Cohesiveness is measured by the internal resistance produced by bread during slicing, which results in deformation of the bread; it characterises the internal cohesion of the bread (Onyango et al., 2011). The cohesiveness of GF sweet potato sourdough bread ranged from 0.53 ± 0.03 (RS/ISD) to 0.66 ± 0.06 (Control/RP), which can be considered superior to the majority of the 11 conventional GF breads (0.20 to 0.44) reported by Matos and Rosell (2012) and standard wheat bread (0.35) reported by Charoenthaikij et al. (2010).

A decrease in the cohesiveness of bread was observed with increasing percentage of sourdough added in the formulation, which is consistent with reported results for GF buckwheat sourdough breads (Moroni et al., 2011). This was probably due to the weakening of the protein-starch and protein-protein interactions, as well as the hydrolysis of starch during sourdough fermentation. Control/RP bread had significantly ($p < 0.05$) higher cohesiveness compared to the control bread (0.56 ± 0.04) as well as the other samples, which positively correlated with the higher moisture of the crumb. These results reflect the cohesiveness of the crumb; a desirable quality (Matos & Rosell, 2012).

4.4.5.4 Gumminess

Crumb gumminess is defined as the energy required to disintegrate bread to facilitate swallowing, which depends on the flour protein content, flour properties, extensibility and tenacity of the dough (Różyło & Laskowski, 2011). The gumminess of GF sweet potato sourdough breads ranged from 8.16 ± 0.76 (RS) to 10.23 ± 1.19 (RS/RK), which is higher than the gumminess reported for GF rice bread (7.23) (Jitrakbumrung & Therdthai, 2014), indicating that addition of sourdough can positively improve the textural characteristics of GF breads. High gumminess is also associated with incorporated hydrocolloids in the GF bread formulation because hydrocolloids can improve the dough stability and enhance the interactions between starch and protein (Rosell, Rojas & De Barber, 2001).

4.4.5.5 Chewiness

Chewiness is the energy required to masticate the bread, indicating the duration of time required to masticate the crumb sample prior to swallowing (Matos & Rosell, 2012). The chewiness of the GF sweet potato sourdough breads ranged from 7.81 ± 0.75 N (RS) to 9.67 ± 1.14 N (RS/RK), which are lower than reported for GF brown rice bread (14.73 N) (Cornejo & Rosell, 2015). Low chewiness could be related to increased starch content (tapioca starch, Hi-Maize starch and corn starch) in the bread formulations (Onyango et al., 2011). These starches are characterised by unique granules, gummy and chewy gelling properties, therefore they are frequently used for improving GF bread quality (Kim, Yun & Jeong, 2015).

RS/RK bread showed the highest chewiness (9.67 ± 1.14 N), followed by the Control bread (8.66 ± 1.38 N), and the chewiness of breads RS (7.81 ± 0.75 N), RS/ISD (8.04 ± 0.35 N) and Control/RP (8.06 ± 0.77 N) were similar. The chewiness of GF sourdough bread is generally lower than normal GF bread, as sourdough LAB produce a range of metabolites such as enzymes, organic acids, and exopolysaccharides that positively impact the crumb texture (Arendt, Ryan & Bello, 2007).

4.4.5.6 Resilience

The resilience of GF sweet potato sourdough breads ranged from 0.18 ± 0.02 (RS/ISD) to 0.30 ± 0.03 (Control/RP). A higher resilience ($p < 0.05$) was obtained for the Control/RP bread, which suggests that retard proofing under refrigeration could produce a more elastic and resilient texture to the bread crumb.

The resilience of RS/ISD bread was lower ($p < 0.05$) than the other breads, which reflected that the increase in added sourdough resulted in a decrease in crumb elasticity. The impaired elasticity is mainly caused by the presence of acids and protein breakdown during sourdough fermentation (Moroni et al., 2011).

4.4.6 Colour of bread crumb and crust

The colour of baked products is dependent on the ingredients used for baking, baking temperature and storage conditions (Mondal & Datta, 2008). As GF breads are generally characterised as being lighter and of poor colour, producing GF bread with a darker colour is therefore desirable. The variations in colour parameters (L^* - lightness, a^* - redness, b^* - yellowness) of the crumb and crust of the baked GF sweet potato sourdough breads are summarised in Table 20. Obvious differences in crumb colour could be observed from the cross sections of sliced crumb (Figure 29 in Section 4.4.1).

Table 20 Crumb and crust colour parameters of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Parameters		Control ¹	RS ¹	RS/RK ¹	RS/ISD ¹	Control/RP ²
Crumb Colour	L^*	65.20 ± 0.78 ^b	71.01 ± 1.56 ^c	70.04 ± 0.12 ^c	65.82 ± 0.25 ^b	64.04 ± 0.32 ^a
	a^*	2.34 ± 0.28 ^d	-0.64 ± 0.20 ^a	-0.22 ± 0.01 ^b	-0.27 ± 0.12 ^b	2.09 ± 0.03 ^c
	b^*	19.81 ± 0.56 ^c	13.45 ± 1.38 ^c	12.24 ± 0.03 ^b	10.85 ± 0.20 ^a	18.58 ± 0.15 ^d
Crust Colour	L^*	51.82 ± 0.95 ^c	56.99 ± 0.72 ^d	57.67 ± 0.78 ^d	46.65 ± 0.79 ^a	50.58 ± 0.16 ^b
	a^*	10.08 ± 0.49 ^b	10.50 ± 0.29 ^b	7.73 ± 1.41 ^a	9.56 ± 2.36 ^b	9.52 ± 0.07 ^b
	b^*	26.26 ± 0.58 ^c	27.13 ± 0.51 ^c	26.41 ± 0.36 ^c	20.31 ± 1.34 ^a	21.98 ± 0.18 ^b

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; L^* = lightness; a^* = redness; b^* = yellowness; n = 9. ^{a-c}Values in the same row with different superscript letters are significantly different ($p < 0.05$).

The Control and Control/RP made with coconut sugar were characterised by a brown yellowish crumb colour and darker brown crust colour, whereas the other three breads (RS, RS/RK, and RS/ISD) made with rice syrup had a white yellowish crumb colour with a lighter yellow brown crust colour. As brown rice flour was the main flour component for bread and sourdough starter, and kumara flour was added in the formulation, a brownish yellow crumb colour was expected due to the natural colour of the composite flour. The significant differences in the crumb and crust colour were dependent on the type of sugar used for making the breads (Tong et al., 2010). The browning of bread is due to the Maillard reactions or caramelisation during bread baking. Different types and amounts of sugar in the formulation impact on the extent of Maillard browning reactions and hence the magnitude of the brown pigment formed (Shen, Chen, & Li, 2018).

4.4.6.1 Lightness (L^*) of bread crumb and crust

The lightness (L^*) of the GF sweet potato sourdough bread crumb is shown in Figure 30, which ranged from 64.04 ± 0.32 to 71.01 ± 1.56 . The lightness results were lower than reported for 11 conventional GF breads (64.71 to 83.83) by Matos and Rosell (2012). The lightness (L^*) for bread crumbs made using coconut sugar (Control and Control/RP) was significantly ($p < 0.05$) lower than all the breads made using rice syrup (RS, RS/RK and RS/ISD). This confirmed the darker colour of the Control and Control/RP bread crumbs, which is desirable as darker bread is usually perceived as being more wholesome (Kim & Yokoyama, 2011). The lightness (L^*) of the bread crusts of the GF sweet potato sourdough ranged from 46.65 ± 0.79 to 57.67 ± 0.78 . The large variability may be due to differences in the levels of available reducing sugars and amino acids in the formulations that impact on Maillard browning and caramelisation (Greene & Bovell-Benjamin, 2004).

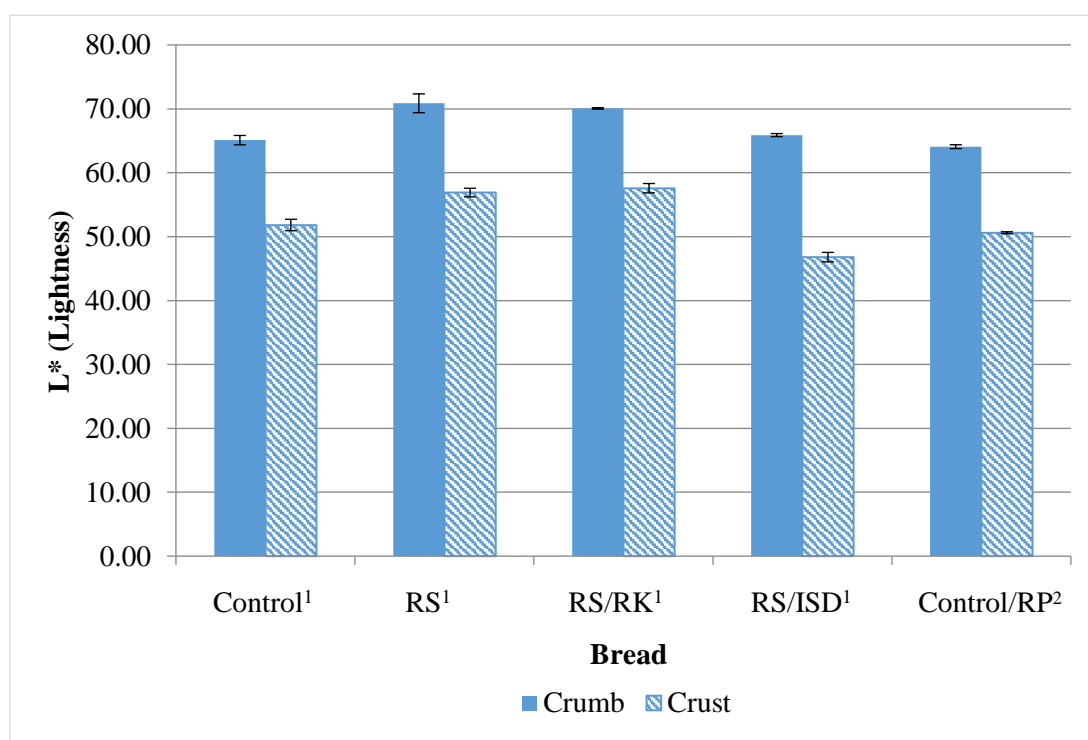


Figure 30 Lightness (L^*) of bread crumb and crust of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 9.

4.4.6.2 Redness (a^*) of bread crumb and crust

Figure 31 shows the redness (a^*) of the GF sweet potato sourdough breads, which ranged from -0.64 ± 0.20 to 2.34 ± 0.28 (positive a^* value = redness, negative a^* value = greenness). The redness (a^*) of bread crumbs made using coconut sugar (Control and Control/RP) were positive, whereas the other breads (RS, RS/RK and RS/ISD) made from rice syrup were negative. This is not surprising as variations in ingredient composition have been reported to have a significant impact on crumb colour (Magnus et al., 1997).

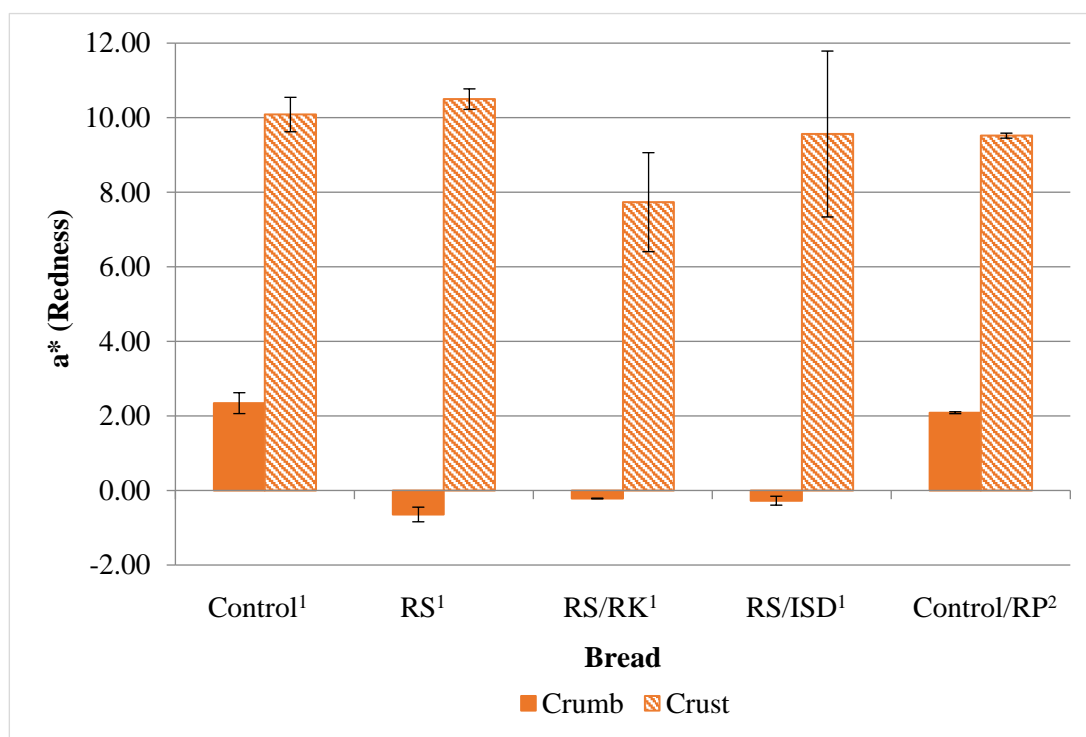


Figure 31 Redness (a^*) of bread crumb and crust of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 9.

The redness (a^*) of all the bread crust samples were positive (7.73 ± 1.41 to 10.50 ± 0.29) due to browning effects, and the incorporation of sweet potato flour also increased the redness of the bread due to the presence of carotenoid pigments (Iwe, Van Zuilichem & Ngoddy, 2000).

4.4.6.3 Yellowness (b^*) of bread crumb and crust

The yellowness (b^*) is characterised by two dimensions, positive b^* value indicates yellowness, and negative b^* value indicates blueness. Figure 32 shows the yellowness (b^*) of the GF sweet potato sourdough bread crumbs and crust. The yellowness (b^*) of the crumb of Control (19.81 ± 0.56) and Control/RP breads (18.58 ± 0.15) were slightly more yellowish-brown (b^*) than the RS (13.45 ± 1.38), RS/RK (12.24 ± 0.03), and RS/ISD (10.85 ± 0.20). According to Gellynck et al. (2009), brown bread is considered healthier than white bread, so a higher b^* value can positively affect the sensory acceptability of the bread.

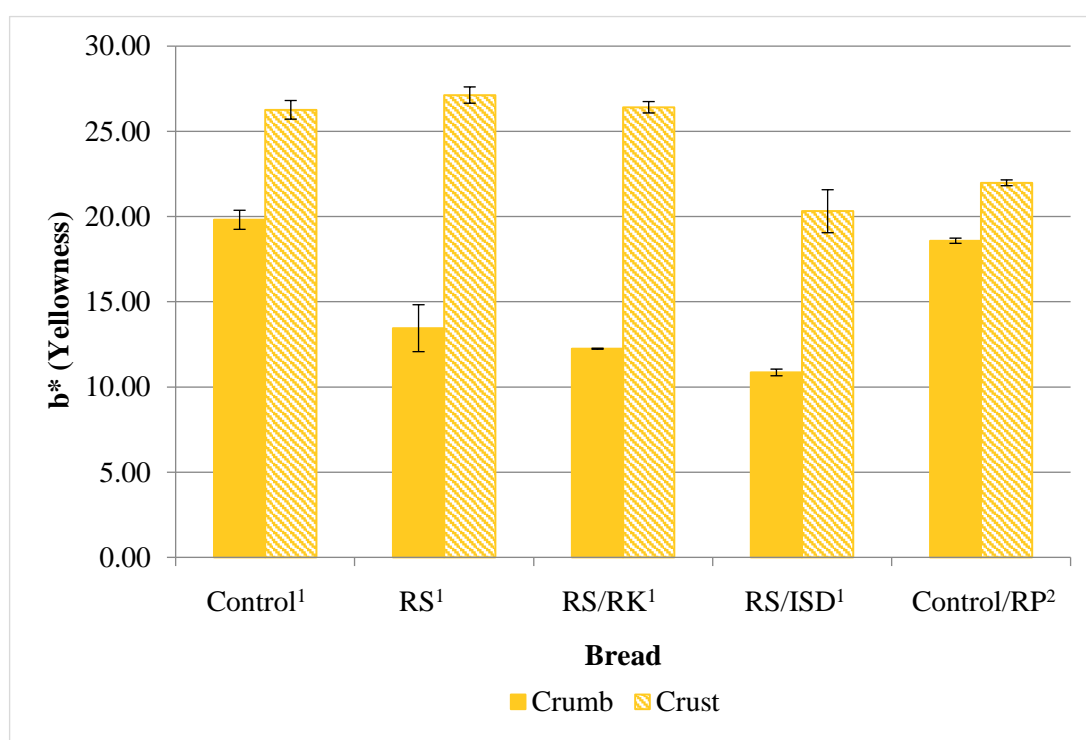


Figure 32 Yellowness (b^*) of bread crumb and crust of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 9.

The lowest bread crust b^* value (20.31 ± 1.34) was the RS/ISD bread, which indicated that higher additions of sourdough may impair the formation of coloured compounds due to Maillard reactions and caramelisation during bread baking. Since the intensity of these reactions depends on the pH of the dough during baking, lower pH requires a longer baking time to produce adequate colour development of the bread crust (Kulp, 2003).

4.4.7 Sensory evaluation

Sensory evaluation is an essential and important assessment technique for the food industry including bakery, as it determines the overall quality and consumer acceptability of food products (Heiniö, 2006). The flavour, texture, appearance and colour of bread, along with perceived freshness are the key attributes in sensory evaluation (Heenan et al., 2008). During dough processing, aromatic and flavour-active compounds are developed through oxidative and enzymatic reactions. Maillard and caramelisation reactions take place during baking and they are responsible for formation of the distinctive aroma and taste of the bread crumb and crust (Ur-Rehman, Paterson & Piggott, 2006). Bread with low firmness and good elasticity, optimal porosity and uniform crumb cell structure can be considered as high quality, and these characteristics can be achieved through optimisation of bread formulations and control of the processing parameters (Mondal & Datta, 2008). The ingredients used for bread-making and the baking conditions also impact on the colour of the bread, and therefore affect consumer acceptability (Gellynck et al., 2009).

Freshly baked GF sweet potato sourdough breads were evaluated for appearance, texture, aroma, taste and overall acceptability and the results are shown in Figure 33. Analysis of the data showed that different formulations and fermentation processes did affect ($p < 0.05$) the mean sensory attribute scores of the GF sweet potato sourdough breads. The ingredients and flavour precursors, as well as the process parameters used in sourdough bread baking can have considerable impact on the microbial composition and activities of the sourdough, and consequently influence the formation of sourdough flavour compounds (Hansen & Schieberle, 2005). Replacing coconut sugar with rice syrup, resulted in higher sensory scores for appearance and texture, but lower scores for aroma, taste and overall acceptability of RS bread than the Control bread. The sugar composition is a determinant factor of bread flavour and taste, as the available sugars and carbohydrates markedly impact on the metabolic products of LAB and yeast during fermentation (Chavan & Chavan, 2011).

GF sweet potato sourdough bread made with rice syrup and reduced amounts of kumara flour (RS/RK) received the lowest sensory scores for aroma (5.46 ± 1.33) and taste (5.70 ± 1.43), and the second lowest overall acceptability (5.77 ± 1.35) as shown in Figure 33. The low sensory scores of these attributes may be due to bland taste and lack of aromatic flavour of RS/RK bread. According to Pereira et al. (2019), sourdough bread prepared with orange-fleshed sweet potato flour has higher moisture, strong yellow colour and produces aromatic compounds such as 2-chloro-octane, dimethyl-decane, and 2-octenal-2-butyl. Therefore, reducing the kumara flour in the GF sourdough bread formulation may have reduced the formation of flavour compounds in the final bread.

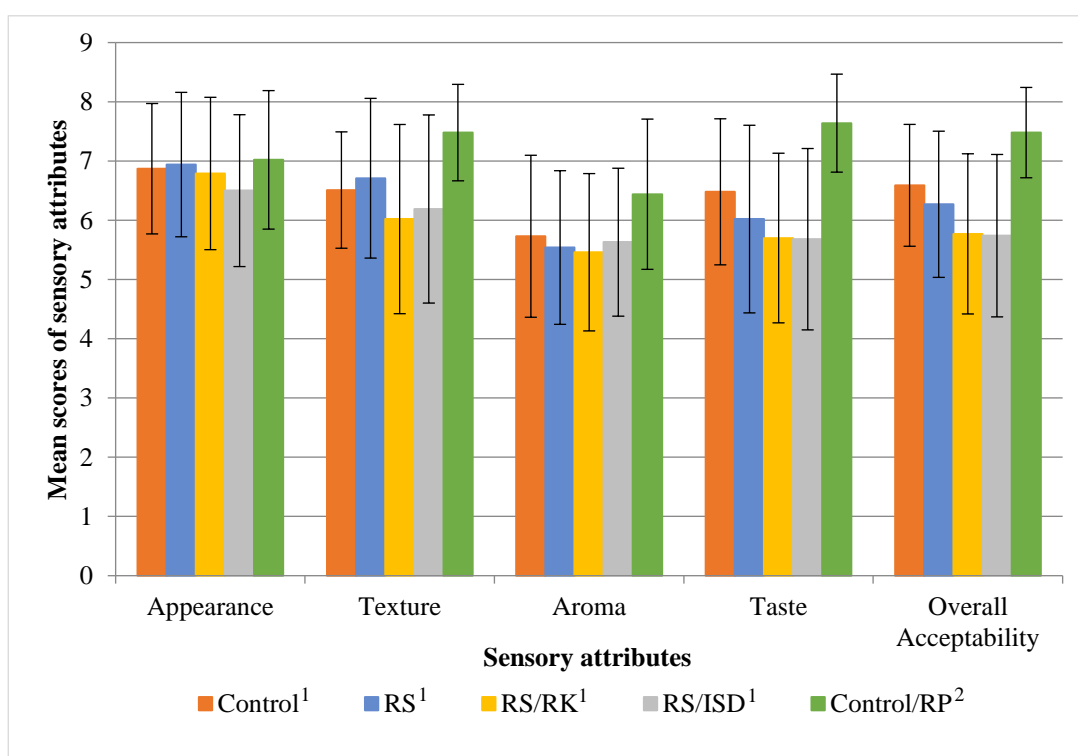


Figure 33 Mean sensory attribute scores of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

¹ Standard fermentation = 1 h fermentation at 37 °C/87 % RH in the prover; ² Retard proofing = 12 h fermentation at 8 °C/87 % RH in the chiller; Control = GF sweet potato sourdough bread with coconut sugar; RS = GF sweet potato sourdough bread with rice syrup; RS/RK = GF sweet potato sourdough bread with rice syrup and reduced kumara flour; RS/ISD = GF sweet potato sourdough bread with rice syrup and increased sourdough starter; Control/RP = GF sweet potato sourdough bread with coconut sugar produced by retard proofing; n = 50.

GF sweet potato sourdough bread made with rice syrup and increased addition of sourdough starter (RS/ISD) also received lower scores for aroma (5.63 ± 1.25) and taste (5.68 ± 1.53), and had the lowest overall acceptability (5.74 ± 1.37), possibly due to its strong acidity and taste. These results are similar to a previous study by Różyło et al. (2015) who used 20 and 30% fresh sourdough starter, resulting in GF sourdough with high scores for taste, aroma and overall

acceptability. The use of 40% sourdough starter in the same study resulted in unfavorable sensory attributes of the bread due to excessive acidification of the dough.

Control/RP bread received the highest mean scores ($p < 0.05$) for all the parameters (7.02 ± 1.17 for appearance, 7.48 ± 0.81 for texture, 6.44 ± 1.27 for aroma, 7.64 ± 0.83 for taste and 7.48 ± 0.76 for overall acceptability). These results may be attributed to the slower fermentation rate of the bread dough by retard proofing. The activity of the wild yeast is reduced under refrigerated temperature, thus a longer fermentation time is required for dough proofing, which results in the production of a sourdough bread with stronger aromatic flavour and more desirable crumb texture (Gómez et al., 2008; Semić et al., 2010).

4.4.8 Summary of Phase 5

The results showed that different formulations and fermentation processes had a strong impact on the baking characteristics and sensory properties of GF sweet potato sourdough breads. Replacing potentially high FODMAP ingredient coconut sugar with low FODMAP ingredient rice syrup (RS, RS/RK, RS/ISD) produced significant ($p < 0.05$) differences in loaf volume, specific volume, water activity (Day 7), crumb and crust colour, and sensory attributes. Reducing kumara flour significantly reduced the loaf weight and loaf volume and increased the baking weight loss of the RS/RK bread ($p < 0.05$). Therefore, the RS/RK bread had higher hardness, gumminess and chewiness of the crumb texture, and lower sensory scores than the other breads. Increased addition of sourdough starter enhanced the sourdough acidification of the bread dough and significantly increased ($p < 0.05$) the loaf volume and specific volume of RS/ISD bread, but negatively impacted the crumb springiness, cohesiveness and resilience. This formulation was not liked by sensory panelists due to the perceived strong acidity aroma and flavour.

However, the Control/RP bread made using the same formulation as the Control bread but with retard proofing did not cause significant differences in loaf volume, water activity (Day 0 and Day 7), crumb springiness, crumb gumminess, or crumb chewiness of the bread compared to the Control bread. Prolonged fermentation time at low temperature proofing condition resulted in significantly higher ($p < 0.05$) loaf weight, lower specific volume and baking weight loss of the bread, which positively influenced the crumb texture by increasing ($p < 0.05$) crumb softness, cohesiveness and resilience. Control/RP bread received the highest scores ($p < 0.05$)

for all the sensory parameters and was well accepted by most of the panelists, demonstrating that retard proofing may produce superior GF sweet potato sourdough bread with strong sourdough aromatic flavours and favorable crumb textures.

CHAPTER 5 OVERALL CONCLUSIONS AND RECOMMENDATIONS

This study quantified the overall FODMAP content of seven commercial GF breads (three conventional GF breads and four GF sourdough breads) produced by a local company in New Zealand using HPAEC-PAD and enzymatic assay. Conventional GF breads and GF sourdough breads analysed in the study were low in FODMAPs. The overall FODMAP contents of the GF sourdough breads were lower than conventional GF breads. By reformulating the existing bread formulations and using retard proofing, the amount of FODMAPs in the GF sourdough bread were further reduced. Although using low FODMAP grains and ingredients, especially replacing the sugar type in the formulation reduced the overall FODMAP content, this negatively affected the baking characteristics and consumer acceptability of the GF sourdough bread. Production of GF sourdough breads by retard proofing, not only provided sufficient time for sourdough LAB and yeast to degrade fructose, GOS and FOS during fermentation, but also enabled sufficient time to develop the full sourdough characteristic flavour, and more desirable crumb structure and other sensory properties. Therefore, retard proofing can be recommended for GF bread manufacturers as a low-cost application for the development of low FODMAP GF breads.

In future studies, the FODMAP profiles of individual grains and ingredients used for bread production could be investigated to provide comprehensive information for optimising formulations to reduce FODMAP levels in bread products. Identification of sourdough microbiota composition from the sourdough starter could be further studied to provide information on the degradation of the FODMAP sugars through specific enzymatic conversions during sourdough fermentation. In addition, there is need for further studies to produce other low FODMAP GF food products for susceptible individuals as part of a holistic dietary therapy for the management of GI symptoms. Sourdough technology has the potential to develop novel products for niche markets.

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APPENDIX

A. Composition of the Media Used for Microbiological Analyses

Table A.1. Composition of the media used in the study

Media and Brand	Ingredients	Composition (g)
MRS agar (CM0361) Oxoid	Peptone	10.0
	Lab-Lemco powder	8.0
	Yeast extract	4.0
	Hydrogen phosphate	2.0
	Sodium acetate 3H ₂ O	5.0
	Tri-ammonium citrate	2.0
	Magnesium sulphate 7H ₂ O	0.2
	Magnesium sulphate 4H ₂ O	0.05
Agar	10.0	
YGC agar (1.16000.0500) Merck	Yeast extract	5.0
	D(+)glucose	20.0
	Chloramphenicol	0.1
	Agar	14.9
Plate count agar (CM0325) Oxoid	Tryptone	5.0
	Yeast extract	2.5
	Glucose	1.0
	Agar	9.0

B. Sensory Evaluation Questionnaire



TITLE of Work: **Gluten Free Sweet Potato Sourdough Bread**

Researcher(s) Introduction

Researchers Name:	Tammy Tian	Supervisors Name:	Dr. Tony Mutukumira Dr. Kay Rutherford
Contact Details:	tammytian0506@gmail.com	Contact Details:	A.N.Mutukumira@massey.ac.nz K.J.Rutherford@massey.ac.nz

You are invited to take part in a *consumer sensory evaluation* to determine the acceptance of the *Gluten Free Sweet Potato Sourdough Bread*.

The types of activities that this work involves include tasting.
Your participation in this activity will take approximately **10 to 15 minutes**.

We will ensure that there is no conflict of interest between the commercial sponsor, Massey University, the participants or a competing product used for comparative purposes.

We are selecting people for this exercise who meet the following criteria:

- Individuals who are 18 years of age and above
- Individuals who are not allergic to the following ingredients stated

The foods you will be tasting contain the following components that can be **harmful** or **cause allergic reactions** with certain groups of people. You will be excluded from taking part if you are allergic, or may be adversely affected by any of the following:

- Traces of egg, sesame seeds, and tree nuts

The information collected in this study will be used to complete a project in partial fulfilment of the Master of Food Technology. Non-participation will not affect your academic performance. No data linked to an individual's identity will be collected. In some circumstances the research may be published.

You should not participate in this trial if you have any doubts concerning the appropriateness of this food with respect to your religious, ethical or cultural beliefs or any other reason.

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- *Completion and return of the questionnaire imply consent. You have the right to decline to answer any particular question.*

If you have any questions about this work, please contact one of the people indicated above.

- *"This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 4000021503. If you have any concerns about the conduct of this research, please contact Dr Brian Finch, Chair, Massey University Human Ethics Committee: Southern A telephone 06 350 5799 x 84459, email humanethicsoutha@massey.ac.nz."*

Gluten Free Sweet Potato Sourdough Bread

• PARTICIPANT CONSENT FORM - INDIVIDUAL

- I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.
- I have advised and discussed the Researcher of any potentially relevant cultural, religious or ethical beliefs that may prevent me from consuming the Foods under consideration.
- I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: _____ Date: _____

Full Name - printed _____

SENSORY EVALUATION OF GLUTEN FREE SWEET POTATO SOURDOUGH BREAD

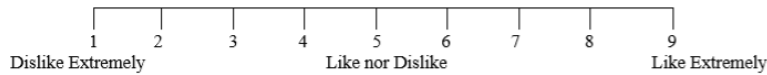
Your will be given five 3-coded samples of gluten free sweet potato sourdough breads.

Please evaluate these samples one by one and use the questionnaire with the corresponding sample code.

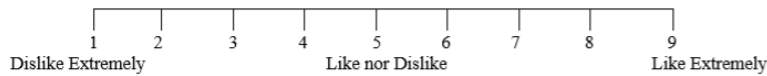
Have a look and taste, and indicate how much you like/dislike it by circle the number on the scale. Use the water and cracker provided to rinse your palate before testing and between two samples.

Sample code 256

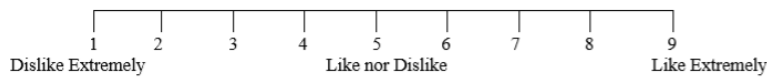
1. How much do you like the **APPEARANCE** of this sample?



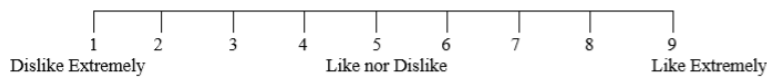
2. How much do you like the **TEXTURE** of this sample?



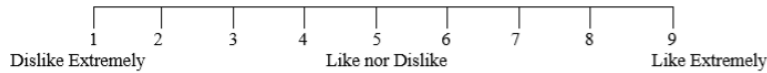
3. How much do you like the **AROMA** of this sample?



4. How much do you like the **TASTE** of this sample?



5. How much do you like the **OVERALL ACCEPTABILITY** of this sample?

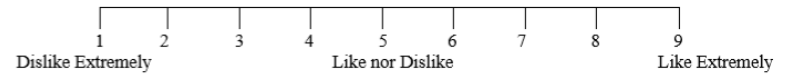


Overall Comment about the product: _____

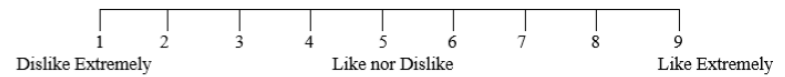
SENSORY EVALUATION OF GLUTEN FREE SWEET POTATO SOURDOUGH BREAD

Sample code 365

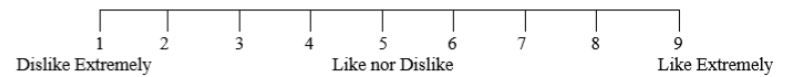
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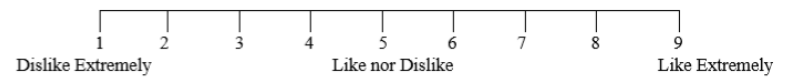
2. How much do you like the **TEXTURE** of this sample?



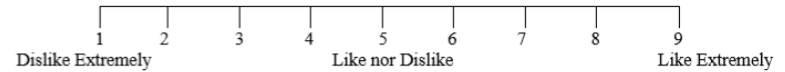
3. How much do you like the **AROMA** of this sample?



4. How much do you like the **TASTE** of this sample?



5. How much do you like the **OVERALL ACCEPTABILITY** of this sample?

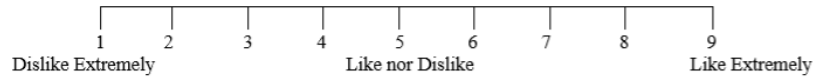


Overall Comment about the product: _____

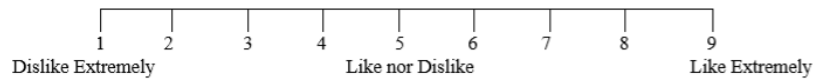
SENSORY EVALUATION OF GLUTEN FREE SWEET POTATO SOURDOUGH BREAD

Sample code 416

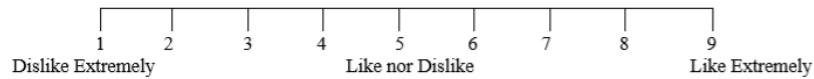
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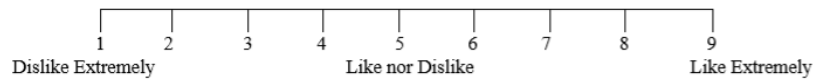
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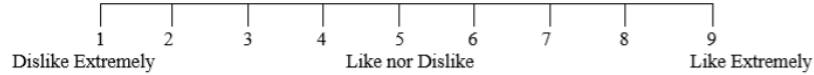
3. How much do you like the **AROMA** of this sample?



4. How much do you like the **TASTE** of this sample?



5. How much do you like the **OVERALL ACCEPTABILITY** of this sample?

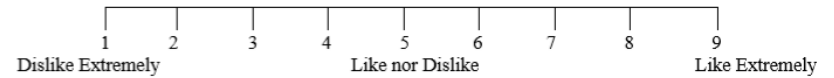


Overall Comment about the product: _____

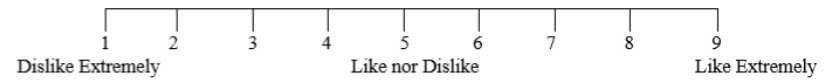
SENSORY EVALUATION OF GLUTEN FREE SWEET POTATO SOURDOUGH BREAD

Sample code 529

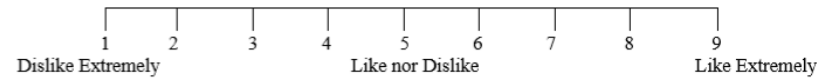
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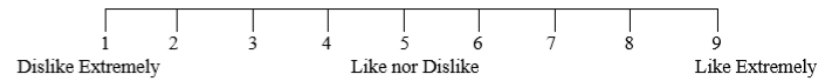
2. How much do you like the **TEXTURE** of this sample?



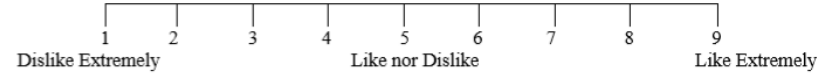
3. How much do you like the **AROMA** of this sample?



4. How much do you like the **TASTE** of this sample?



5. How much do you like the **OVERALL ACCEPTABILITY** of this sample?

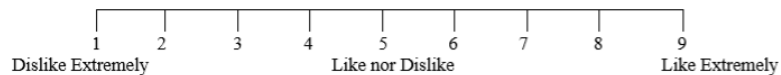


Overall Comment about the product: _____

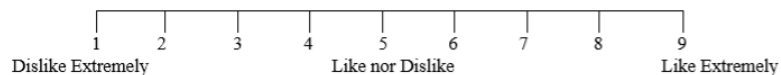
SENSORY EVALUATION OF GLUTEN FREE SWEET POTATO SOURDOUGH BREAD

Sample code 659

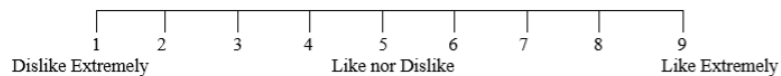
1. How much do you like the **APPEARANCE** of this sample?



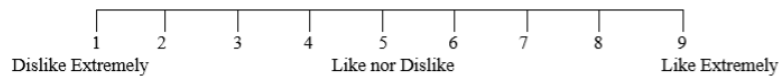
2. How much do you like the **TEXTURE** of this sample?



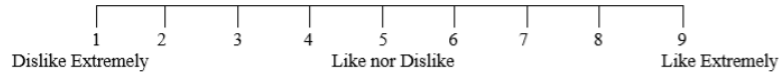
3. How much do you like the **AROMA** of this sample?



4. How much do you like the **TASTE** of this sample?



5. How much do you like the **OVERALL ACCEPTABILITY** of this sample?



Overall Comment about the product: _____

Thank you! 😊

C. Data Analysis

Table C.1 Raw data of LAB and yeast counts of GF sourdough starter (SD) during 72 h propagation, and bread dough (BD) samples before proofing (BP) and after proofing (AP) of GF sweet potato sourdough breads (n = 2)

Sample		Replication	LAB count	Dilution factor	LAB (CFU/g)	LAB Log(CFU/g)			Yeast count	Dilution factor	Yeast (CFU/g)	Yeast Log(CFU/g)		
SD	UD - 0 h	1	20	1.00E-07	2.00E+08	8.30	Mean	8.29	1	1.00E-04	1.00E+04	4.00	Mean	4.15
		2	19	1.00E-07	1.90E+08	8.28	SD	0.02	2	1.00E-04	2.00E+04	4.30	SD	0.21
	FD - 24 h	1	441	1.00E-06	4.41E+08	8.64	Mean	8.59	4	1.00E-04	4.00E+04	4.60	Mean	4.65
		2	336	1.00E-06	3.36E+08	8.53	SD	0.08	5	1.00E-04	5.00E+04	4.70	SD	0.07
	FD - 48 h	1	283	1.00E-07	2.83E+09	9.45	Mean	9.43	9	1.00E-04	9.00E+04	4.95	Mean	5.00
		2	252	1.00E-07	2.52E+09	9.40	SD	0.04	11	1.00E-04	1.10E+05	5.04	SD	0.06
	FD - 72 h	1	278	1.00E-07	2.78E+09	9.44	Mean	9.45	28	1.00E-04	2.80E+05	5.45	Mean	5.44
		2	286	1.00E-07	2.86E+09	9.46	SD	0.01	27	1.00E-04	2.70E+05	5.43	SD	0.01
Control	BDBP	1	73	1.00E-06	7.30E+07	7.86	Mean	7.89	92	1.00E-06	9.20E+07	7.96	Mean	7.96
		2	82	1.00E-06	8.20E+07	7.91	SD	0.04	90	1.00E-06	9.00E+07	7.95	SD	0.01
	BDAP	1	296	1.00E-06	2.96E+08	8.47	Mean	8.45	17	1.00E-07	1.70E+08	8.23	Mean	8.22
		2	273	1.00E-06	2.73E+08	8.44	SD	0.02	16	1.00E-07	1.60E+08	8.20	SD	0.02
RS	BDBP	1	22	1.00E-06	2.20E+07	7.34	Mean	7.23	56	1.00E-06	5.60E+07	7.75	Mean	7.80
		2	13	1.00E-06	1.30E+07	7.11	SD	0.16	70	1.00E-06	7.00E+07	7.85	SD	0.07
	BDAP	1	25	1.00E-07	2.50E+08	8.40	Mean	8.41	160	1.00E-06	1.60E+08	8.20	Mean	8.21
		2	26	1.00E-07	2.60E+08	8.41	SD	0.01	162	1.00E-06	1.62E+08	8.21	SD	0.00
RS/RK	BDBP	1	32	1.00E-06	3.20E+07	7.51	Mean	7.54	71	1.00E-06	7.10E+07	7.85	Mean	7.77
		2	38	1.00E-06	3.80E+07	7.58	SD	0.05	48	1.00E-06	4.80E+07	7.68	SD	0.12
	BDAP	1	223	1.00E-06	2.23E+08	8.35	Mean	8.38	161	1.00E-06	1.61E+08	8.21	Mean	8.21
		2	260	1.00E-06	2.60E+08	8.41	SD	0.05	163	1.00E-06	1.63E+08	8.21	SD	0.00
RS/ISD	BDBP	1	116	1.00E-06	1.16E+08	8.06	Mean	8.05	76	1.00E-06	7.60E+07	7.88	Mean	7.92
		2	108	1.00E-06	1.08E+08	8.03	SD	0.02	89	1.00E-06	8.90E+07	7.95	SD	0.05
	BDAP	1	386	1.00E-06	3.86E+08	8.59	Mean	8.59	204	1.00E-06	2.04E+08	8.31	Mean	8.32
		2	390	1.00E-06	3.90E+08	8.59	SD	0.00	216	1.00E-06	2.16E+08	8.33	SD	0.02
Control/RP	BDBP	1	24	1.00E-06	2.40E+07	7.38	Mean	7.45	85	1.00E-06	8.50E+07	7.93	Mean	7.91
		2	33	1.00E-06	3.30E+07	7.52	SD	0.10	76	1.00E-06	7.60E+07	7.88	SD	0.03
	BDAP	1	218	1.00E-06	2.18E+08	8.34	Mean	8.35	195	1.00E-06	1.95E+08	8.29	Mean	8.23
		2	228	1.00E-06	2.28E+08	8.36	SD	0.01	149	1.00E-06	1.49E+08	8.17	SD	0.08

Table C.2 Raw data of pH and TTA of GF sourdough starter (SD) during 72 h propagation, bread dough (BD) samples before proofing (BP) and after proofing (AP), and bread samples of GF sweet potato sourdough breads (n = 3)

Sample		pH value					Total titratable acidity (TTA) 0.1 mol/L NaOH				
		Replication			Mean	SD	Replication			Mean	SD
		1	2	3			1	2	3		
SD	UD - 0 h	5.69	5.65	5.66	5.67	0.02	4.30	4.35	4.40	4.35	0.05
	FD - 24 h	4.13	4.16	4.15	4.15	0.02	10.41	10.46	10.46	10.44	0.03
	FD - 48 h	4.03	4.05	4.06	4.05	0.02	10.86	10.91	10.86	10.88	0.03
	FD - 72 h	3.89	3.90	3.70	3.83	0.11	11.31	11.21	11.11	11.21	0.10
Control	BDBP	4.52	4.56	4.53	4.54	0.02	4.10	4.15	4.05	4.10	0.05
	BDAP	4.42	4.45	4.44	4.44	0.02	4.30	4.30	4.25	4.29	0.03
	Bread 1	4.65	4.66	4.65	4.58	0.06	3.50	3.55	3.45	3.52	0.05
	Bread 2	4.51	4.53	4.50			3.55	3.50	3.50		
	Bread 3	4.55	4.57	4.58			3.60	3.55	3.45		
RS	BDBP	4.48	4.45	4.47	4.47	0.02	4.35	4.40	4.35	4.37	0.03
	BDAP	4.32	4.34	4.32	4.33	0.01	4.56	4.61	4.56	4.57	0.03
	Bread 1	4.53	4.51	4.50	4.51	0.01	4.25	4.35	4.25	4.30	0.06
	Bread 2	4.52	4.49	4.51			4.30	4.40	4.35		
	Bread 3	4.53	4.52	4.50			4.30	4.25	4.20		
RS/RK	BDBP	4.39	4.40	4.38	4.39	0.01	4.20	4.30	4.20	4.24	0.06
	BDAP	4.20	4.19	4.20	4.20	0.01	4.45	4.50	4.45	4.47	0.03
	Bread 1	4.43	4.44	4.45	4.42	0.04	4.10	4.30	4.40	4.23	0.11
	Bread 2	4.47	4.45	4.42			4.20	4.25	4.10		
	Bread 3	4.36	4.35	4.39			4.15	4.35	4.15		
RS/ISD	BDBP	4.24	4.25	4.24	4.24	0.01	4.91	5.01	4.96	4.96	0.05
	BDAP	4.19	4.18	4.20	4.19	0.01	5.36	5.41	5.31	5.36	0.05
	Bread 1	4.32	4.33	4.31	4.28	0.05	4.86	4.86	4.91	4.88	0.06
	Bread 2	4.29	4.31	4.33			4.91	4.91	4.76		
	Bread 3	4.21	4.21	4.23			4.91	4.96	4.86		
Control/RP	BDBP	4.55	4.56	4.56	4.56	0.01	4.10	4.05	4.10	4.09	0.03
	BDAP	4.54	4.52	4.51	4.52	0.02	4.25	4.30	4.35	4.30	0.05
	Bread 1	4.58	4.60	4.61	4.61	0.03	3.55	3.50	3.45	3.44	0.08
	Bread 2	4.57	4.58	4.59			3.45	3.45	3.40		
	Bread 3	4.64	4.63	4.65			3.30	3.50	3.35		

Table C.3 Raw data of organic acid standards used for HPLC standard curve

Standards	Concentration (%) (w/v)	Replication	Area	Retention Time	Average Retention Time
Lactic acid	0.150	1	1567397	17.094	17.069
		2	1571290	17.096	
	0.120	1	1250750	17.092	
		2	1252736	17.078	
	0.100	1	1056772	17.084	
		2	1057989	17.070	
	0.060	1	633046	17.064	
		2	629973	17.064	
	0.030	1	303933	17.052	
		2	302662	17.060	
	0.015	1	150972	17.072	
		2	151641	17.049	
	0.006	1	62494	17.039	
		2	61043	17.046	
Acetic acid	0.100	1	1357944	19.907	19.920
		2	1359869	19.945	
	0.075	1	1025413	19.947	
		2	1030072	19.947	
	0.050	1	647115	19.943	
		2	651776	19.903	
	0.020	1	259143	19.913	
		2	235677	19.903	
	0.015	1	195156	19.913	
		2	196283	19.921	
	0.010	1	117276	19.918	
		2	118739	19.910	
	0.005	1	57622	19.918	
		2	59004	19.890	

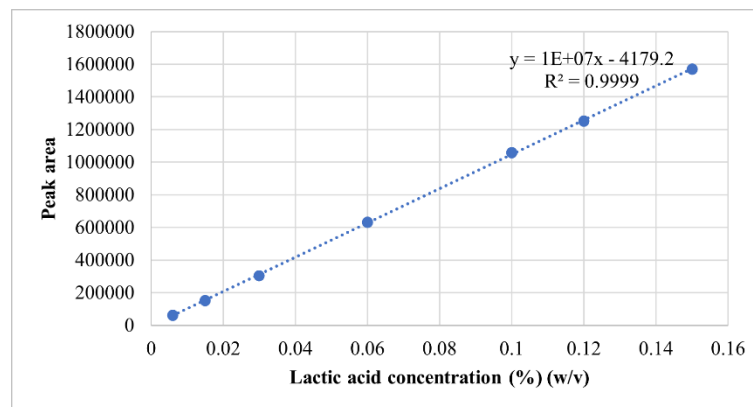


Figure C.1 HPLC lactic acid standard curve

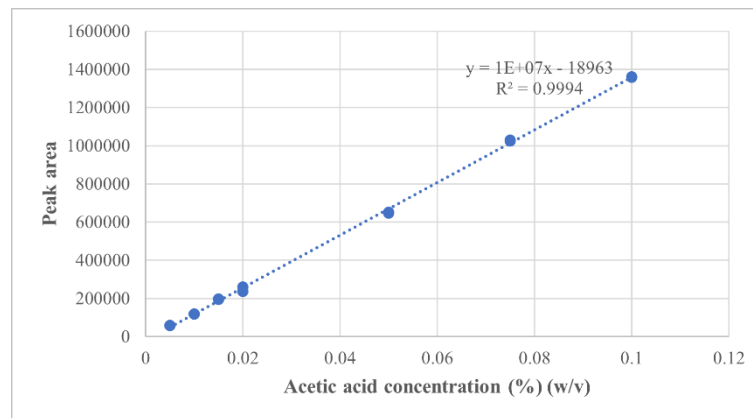


Figure C.2 HPLC acetic acid standard curve

Table C.4 Raw data of HPLC organic acids analysis of GF sourdough starter (SD) during 72 h propagation, bread dough (BD) samples before proofing (BP) and after proofing (AP), and bread samples of GF sweet potato sourdough breads (n = 4)

Sample		Replication	Lactic acid				Acetic acid			
			Peak area	Concentration (g/100g)	Mean	SD	Peak area	Concentration (g/100g)	Mean	SD
SD	UD - 0 h	1	11886	0.16	0.16	0.00	14041	0.33	0.34	0.01
		1	12060	0.16			15871	0.35		
		2	11402	0.16			14272	0.33		
		2	11145	0.15			14946	0.34		
		2	11145	0.15			14946	0.34		
	FD - 24 h	1	85810	0.90	0.92	0.05	23446	0.42	0.43	0.00
		1	95460	1.00			23367	0.42		
		2	86109	0.90			24327	0.43		
		2	85134	0.89			23785	0.43		
		2	85134	0.89			23785	0.43		
	FD - 48 h	1	119568	1.24	1.17	0.07	27865	0.47	0.45	0.02
		1	118051	1.22			23439	0.42		
		2	107928	1.12			24103	0.43		
		2	107065	1.11			28070	0.47		
		2	107065	1.11			28070	0.47		
	FD - 72 h	1	111731	1.16	1.22	0.05	24918	0.44	0.49	0.05
1		116664	1.21	26852			0.46			
2		122460	1.27	30735			0.50			
2		122410	1.27	36761			0.56			
2		122410	1.27	36761			0.56			
Control	BDBP	1	39169	0.43	0.43	0.01	7552	0.27	0.27	0.00
		1	38035	0.42			8320	0.27		
		2	38924	0.43			8628	0.28		
		2	37546	0.42			8225	0.27		
	BDAP	1	44562	0.49	0.49	0.01	10047	0.29	0.29	0.00
		1	45350	0.50			10484	0.29		
		2	43757	0.48			10089	0.29		
		2	45077	0.49			10542	0.30		
RS	BDBP	1	22482	0.27	0.27	0.00	2390	0.21	0.23	0.01
		1	22465	0.27			3999	0.23		
		2	22376	0.27			4304	0.23		
		2	22630	0.27			3927	0.23		
	BDAP	1	28295	0.32	0.32	0.01	4436	0.23	0.24	0.00
		1	27042	0.31			5051	0.24		
		2	28118	0.32			4990	0.24		
		2	26751	0.31			4664	0.24		

Sample		Replication	Lactic acid				Acetic acid			
			Peak area	Concentration (g/100g)	Mean	SD	Peak area	Concentration (g/100g)	Mean	SD
RS/RK	BDBP	1	26528	0.31	0.31	0.00	6536	0.25	0.26	0.00
		1	26513	0.31			7439	0.26		
		2	26811	0.31			7410	0.26		
		2	26459	0.31			6927	0.26		
	BDAP	1	28558	0.33	0.33	0.01	7699	0.27	0.27	0.01
		1	29060	0.33			7296	0.26		
		2	28034	0.32			7738	0.27		
		2	27730	0.32			7376	0.26		
RS/ISD	BDBP	1	53053	0.57	0.53	0.04	28881	0.48	0.47	0.01
		1	50176	0.54			28073	0.47		
		2	45346	0.50			26923	0.46		
		2	46081	0.50			26530	0.45		
	BDAP	1	58190	0.62	0.57	0.06	29150	0.48	0.49	0.00
		1	56675	0.61			29547	0.49		
		2	47187	0.51			30076	0.49		
		2	47895	0.52			29411	0.48		
Control/RP	BDBP	1	52371	0.57	0.55	0.01	11848	0.31	0.31	0.00
		1	50339	0.55			11724	0.31		
		2	49720	0.54			11703	0.31		
		2	48974	0.53			11622	0.31		
	BDAP	1	53135	0.57	0.56	0.01	13319	0.32	0.31	0.01
		1	51080	0.55			11861	0.31		
		2	51969	0.56			12243	0.31		
		2	52978	0.57			12302	0.31		
Control	Bread	1	40069	0.44	0.47	0.03	6756	0.26	0.26	0.01
		1	43352	0.48			6532	0.25		
		2	40882	0.45			7591	0.27		
		2	46096	0.50			6338	0.25		
		1	24530	0.29			4765	0.24		
RS	Bread	1	24916	0.29	0.27	0.03	5281	0.24	0.24	0.00
		2	20426	0.25			4751	0.24		
		2	20296	0.24			4779	0.24		
		1	20296	0.24			4779	0.24		

Sample		Replication	Lactic acid				Acetic acid			
			Peak area	Concentration (g/100g)	Mean	SD	Peak area	Concentration (g/100g)	Mean	SD
RS/RK	Bread	1	20963	0.25	0.27	0.03	4303	0.23	0.23	0.00
		1	20744	0.25			4664	0.24		
		2	24750	0.29			4606	0.24		
		2	25931	0.30			4542	0.24		
RS/ISD	Bread	1	32230	0.36	0.38	0.01	11460	0.30	0.30	0.00
		1	33405	0.38			11013	0.30		
		2	34873	0.39			10605	0.30		
		2	33585	0.38			11216	0.30		
Control/RP	Bread	1	40024	0.44	0.44	0.01	2216	0.21	0.22	0.01
		1	39732	0.44			2589	0.22		
		2	40423	0.45			3507	0.22		
		2	41004	0.45			4065	0.23		

Table C.5 Raw data of HPAEC FODMAP analysis of seven commercial GF breads, GF sourdough starter (SD) during 72 h propagation, bread dough (BD) samples before proofing (BP) and after proofing (AP), and bread samples of GF sweet potato sourdough breads (n = 2)

Sample		Replication	Fructose (g/100g wet)	Mean (g/100g wet)	SD	Glucose (g/100g wet)	Mean (g/100g wet)	SD	Excess fructose (g/100g wet)	Mean (g/100g wet)	SD
GF Breads	GF1	1	0.124	0.128	0.005	0.103	0.107	0.006	0.021	0.021	0.000
		2	0.132			0.111			0.021		
	GF2	1	0.155	0.162	0.010	0.103	0.107	0.005	0.053	0.055	0.004
		2	0.169			0.110			0.058		
	GF3	1	0.177	0.178	0.002	0.117	0.120	0.004	0.060	0.058	0.003
		2	0.179			0.123			0.056		
	GFSD1	1	0.210	0.194	0.023	0.153	0.145	0.012	0.057	0.050	0.011
		2	0.178			0.136			0.042		
	GFSD2	1	0.170	0.174	0.007	0.124	0.128	0.006	0.045	0.046	0.001
		2	0.179			0.132			0.047		
	GFSD3	1	0.078	0.081	0.003	0.106	0.112	0.009	0	0	0
		2	0.083			0.118			0		
	GFSDNY	1	0.029	0.029	0.000	0.130	0.132	0.002	0	0	0
		2	0.029			0.133			0		
SD	UD - 0 h	1	0.076	0.080	0.005	0.095	0.099	0.006	0	0	0
		2	0.083			0.103			0		
	FD - 24 h	1	0.007	0.007	0.000	0.105	0.106	0.001	0	0	0
		2	0.007			0.107			0		
	FD - 48 h	1	0.002	0.002	0.000	0.111	0.114	0.004	0	0	0
		2	0.002			0.117			0		
	FD - 72 h	1	0.001	0.001	0.000	0.070	0.068	0.002	0	0	0
		2	0.001			0.067			0		
Control	BDBP	1	0.169	0.171	0.003	0.145	0.148	0.004	0.023	0.023	0.001
		2	0.172			0.151			0.022		
	BDAP	1	0.154	0.155	0.001	0.123	0.126	0.003	0.031	0.029	0.002
		2	0.156			0.128			0.028		
RS	BDBP	1	0.085	0.085	0.000	0.131	0.131	0.001	0	0	0
		2	0.085			0.130			0		
	BDAP	1	0.065	0.065	0.001	0.135	0.133	0.003	0	0	0
		2	0.064			0.132			0		

Sample		Replication	Fructose (g/100g wet)	Mean (g/100g wet)	SD	Glucose (g/100g wet)	Mean (g/100g wet)	SD	Excess fructose (g/100g wet)	Mean (g/100g wet)	SD
RS/RK	BDBP	1	0.053	0.055	0.003	0.104	0.105	0.000	0	0	0
		2	0.057			0.105			0		
	BDAP	1	0.039	0.039	0.000	0.098	0.098	0.000	0	0	0
		2	0.039			0.097			0		
RS/ISD	BDBP	1	0.055	0.054	0.001	0.105	0.104	0.002	0	0	0
		2	0.054			0.102			0		
	BDAP	1	0.046	0.047	0.000	0.094	0.093	0.001	0	0	0
		2	0.047			0.092			0		
Control/RP	BDBP	1	0.182	0.188	0.009	0.103	0.103	0.001	0.079	0.086	0.009
		2	0.194			0.102			0.092		
	BDAP	1	0.161	0.162	0.001	0.103	0.104	0.001	0.058	0.058	0.000
		2	0.162			0.105			0.058		
Control	Bread	1	0.205	0.205	0.000	0.173	0.176	0.004	0.032	0.029	0.004
		2	0.205			0.179			0.026		
RS	Bread	1	0.111	0.111	0.001	0.161	0.160	0.001	0	0	0
		2	0.110			0.159			0		
RS/RK	Bread	1	0.084	0.082	0.003	0.159	0.153	0.009	0	0	0
		2	0.080			0.147			0		
RS/ISD	Bread	1	0.091	0.089	0.002	0.135	0.135	0.001	0	0	0
		2	0.087			0.136			0		
Control/RP	Bread	1	0.181	0.179	0.003	0.158	0.158	0.000	0.024	0.021	0.003
		2	0.177			0.158			0.019		

Sample		Replication	Sorbitol (g/100g wet)	Mean (g/100g wet)	SD	Mannitol (g/100g wet)	Mean (g/100g wet)	SD	Raffinose (g/100g wet)	Mean (g/100g wet)	SD	
GF Breads	GF1	1	0.038	0.039	0.002	0.014	0.014	0.001	ND	ND	ND	
		2	0.040			0.015			ND			
	GF2	1	0.031	0.031	0.001	ND	ND	ND	ND	ND	ND	
		2	0.032			ND			ND			
	GF3	1	0.031	0.030	0.001	0.001	0.001	0.000	0.116	0.120	0.006	
		2	0.029			0.001			0.124			
	GFSD1	1	0.004	0.004	0.000	0.035	0.034	0.000	ND	ND	ND	
		2	0.004			0.034			ND			
	GFSD2	1	0.005	0.005	0.000	0.033	0.034	0.000	ND	ND	ND	
		2	0.005			0.034			ND			
	GFSD3	1	0.004	0.003	0.000	0.027	0.026	0.000	0.036	0.036	0.000	
		2	0.003			0.026			0.036			
	GFSDNY	1	0.001	0.001	0.000	0.032	0.033	0.000	0.018	0.018	0.000	
		2	0.001			0.033			0.018			
SD	UD - 0 h	1	0.003	0.003	0.000	0.019	0.020	0.001	0.050	0.052	0.004	
		2	0.003			0.020			0.055			
	FD - 24 h	1	0.004	0.004	0.000	0.032	0.032	0.000	0.018	0.018	0.000	
		2	0.004			0.032			0.018			
	FD - 48 h	1	0.004	0.004	0.000	0.034	0.034	0.001	0.007	0.007	0.000	
		2	0.004			0.035			0.007			
	FD - 72 h	1	0.006	0.006	0.000	0.034	0.033	0.001	0.003	0.002	0.000	
		2	0.006			0.033			0.002			
	Control	BDBP	1	0.004	0.004	0.000	0.033	0.033	0.000	0.002	0.002	0.000
			2	0.004			0.034			0.002		
BDAP		1	0.004	0.004	0.000	0.033	0.033	0.000	0.002	0.002	0.000	
		2	0.004			0.033			0.002			
RS	BDBP	1	0.004	0.004	0.000	0.024	0.024	0.000	ND	ND	ND	
		2	0.004			0.025			ND			
	BDAP	1	0.004	0.004	0.000	0.026	0.025	0.000	ND	ND	ND	
		2	0.003			0.025			ND			

ND = not detected.

Sample		Replication	Sorbitol (g/100g wet)	Mean (g/100g wet)	SD	Mannitol (g/100g wet)	Mean (g/100g wet)	SD	Raffinose (g/100g wet)	Mean (g/100g wet)	SD
RS/RK	BDBP	1	0.003	0.004	0.000	0.025	0.025	0.000	ND	ND	ND
		2	0.004			0.025			ND		
	BDAP	1	0.003	0.003	0.000	0.026	0.026	0.000	ND	ND	ND
		2	0.003			0.025			ND		
RS/ISD	BDBP	1	0.002	0.002	0.000	0.028	0.028	0.000	ND	ND	ND
		2	0.002			0.028			ND		
	BDAP	1	0.002	0.002	0.000	0.029	0.029	0.000	ND	ND	ND
		2	0.002			0.029			ND		
Control/RP	BDBP	1	0.003	0.003	0.000	0.033	0.032	0.000	0.001	0.001	0.000
		2	0.003			0.032			0.001		
	BDAP	1	0.003	0.003	0.000	0.034	0.034	0.000	ND	ND	ND
		2	0.003			0.034			ND		
Control	Bread	1	0.005	0.005	0.000	0.040	0.040	0.000	ND	ND	ND
		2	0.005			0.040			ND		
RS	Bread	1	0.005	0.005	0.000	0.030	0.030	0.000	ND	ND	ND
		2	0.005			0.030			ND		
RS/RK	Bread	1	0.006	0.006	0.000	0.030	0.030	0.000	ND	ND	ND
		2	0.006			0.030			ND		
RS/ISD	Bread	1	0.005	0.005	0.000	0.031	0.032	0.001	ND	ND	ND
		2	0.005			0.032			ND		
Control/RP	Bread	1	0.005	0.005	0.000	0.041	0.040	0.001	ND	ND	ND
		2	0.005			0.039			ND		

ND = not detected.

Sample		Replication	Stachyose (g/100g wet)	Mean (g/100g wet)	SD	Kestose (g/100g wet)	Mean (g/100g wet)	SD	Nystose (g/100g wet)	Mean (g/100g wet)	SD
GF Breads	GF1	1	0.000	0.000	0.000	ND	ND	ND	0.018	0.018	0.001
		2	0.000			ND			0.018		
	GF2	1	0.008	0.009	0.000	ND	ND	ND	0.055	0.058	0.004
		2	0.009			ND			0.061		
	GF3	1	0.053	0.056	0.003	ND	ND	ND	0.071	0.074	0.004
		2	0.058			ND			0.077		
	GFSD1	1	0.005	0.005	0.000	ND	ND	ND	0.037	0.035	0.002
		2	0.004			ND			0.034		
	GFSD2	1	0.007	0.007	0.000	ND	ND	ND	0.032	0.033	0.001
		2	0.007			ND			0.034		
	GFSD3	1	0.005	0.005	0.000	ND	ND	ND	0.019	0.020	0.002
		2	0.005			ND			0.022		
	GFSDNY	1	0.015	0.015	0.000	ND	ND	ND	0.027	0.027	0.000
		2	0.015			ND			0.027		
SD	UD - 0 h	1	0.007	0.008	0.000	ND	ND	ND	0.025	0.026	0.001
		2	0.008			ND			0.027		
	FD - 24 h	1	0.032	0.032	0.000	ND	ND	ND	0.009	0.009	0.000
		2	0.032			ND			0.009		
	FD - 48 h	1	0.041	0.042	0.002	ND	ND	ND	0.010	0.011	0.000
		2	0.044			ND			0.011		
	FD - 72 h	1	0.021	0.020	0.000	ND	ND	ND	0.009	0.008	0.000
		2	0.020			ND			0.008		
Control	BDBP	1	0.011	0.012	0.001	ND	ND	ND	0.038	0.039	0.002
		2	0.012			ND			0.040		
	BDAP	1	0.013	0.013	0.001	ND	ND	ND	0.035	0.036	0.001
		2	0.014			ND			0.037		
RS	BDBP	1	0.010	0.010	0.000	ND	ND	ND	0.067	0.066	0.002
		2	0.010			ND			0.064		
	BDAP	1	0.012	0.012	0.000	ND	ND	ND	0.077	0.076	0.001
		2	0.012			ND			0.076		

ND = not detected.

Sample		Replication	Stachyose (g/100g wet)	Mean (g/100g wet)	SD	Kestose (g/100g wet)	Mean (g/100g wet)	SD	Nystose (g/100g wet)	Mean (g/100g wet)	SD
RS/RK	BDBP	1	0.004	0.004	0.000	ND	ND	ND	0.044	0.045	0.002
		2	0.004			ND			0.047		
	BDAP	1	0.005	0.005	0.000	ND	ND	ND	0.051	0.051	0.000
		2	0.005			ND			0.051		
RS/ISD	BDBP	1	0.005	0.005	0.000	ND	ND	ND	0.054	0.055	0.000
		2	0.005			ND			0.055		
	BDAP	1	0.004	0.004	0.000	ND	ND	ND	0.044	0.044	0.000
		2	0.004			ND			0.044		
Control/RP	BDBP	1	0.005	0.005	0.000	ND	ND	ND	0.022	0.023	0.001
		2	0.006			ND			0.023		
	BDAP	1	0.005	0.005	0.000	ND	ND	ND	0.024	0.024	0.000
		2	0.005			ND			0.024		
Control	Bread	1	0.012	0.012	0.001	ND	ND	ND	0.045	0.046	0.002
		2	0.013			ND			0.048		
RS	Bread	1	0.010	0.010	0.000	ND	ND	ND	0.061	0.062	0.000
		2	0.010			ND			0.062		
RS/RK	Bread	1	0.006	0.006	0.000	ND	ND	ND	0.053	0.053	0.000
		2	0.005			ND			0.053		
RS/ISD	Bread	1	0.007	0.007	0.000	ND	ND	ND	0.055	0.055	0.000
		2	0.006			ND			0.055		
Control/RP	Bread	1	0.010	0.010	0.000	ND	ND	ND	0.043	0.044	0.001
		2	0.010			ND			0.045		

ND = not detected.

Table C.6 Raw data of total fructans measurement of seven commercial GF breads, GF sourdough starter (SD) during 72 h propagation, bread dough (BD) samples before proofing (BP) and after proofing (AP), and bread samples of GF sweet potato sourdough breads (n = 2)

Sample		Weight before freeze dry (g)	Weight after freeze dry (g)	Dry (%)	Replication	Total fructan (g/100g dry)	Total fructan (g/100g wet)	Mean (g/100g wet)	SD	Serve size (g)	Total fructan (g/per serve)
Seven Commercial GF Breads	GF1	500.11	284.53	56.89	1	0.1420	0.0808	0.0788	0.0028	66	0.0520
					2	0.1350	0.0768				
	GF2	503.15	294.16	58.46	1	0.2020	0.1181	0.1201	0.0029	73	0.0877
					2	0.2090	0.1222				
	GF3	501.60	327.93	65.38	1	0.2760	0.1804	0.1815	0.0015	73	0.1325
					2	0.2790	0.1824				
	GFSD1	500.00	267.10	53.43	1	0.2010	0.1074	0.1085	0.0015	100	0.1085
					2	0.2050	0.1095				
	GFSD2	500.00	269.10	53.82	1	0.1340	0.0721	0.0711	0.0015	73	0.0519
					2	0.1300	0.0700				
	GFSD3	503.35	285.10	56.64	1	0.0280	0.0159	0.0148	0.0016	40	0.0059
					2	0.0240	0.0136				
	GFSDNY	501.10	261.71	52.23	1	0.1080	0.0564	0.0546	0.0026	40	0.0218
					2	0.1010	0.0528				
SD	UD - 0 h	254.10	116.04	45.67	1	0.0380	0.0174	0.0164	0.0013	-	-
					2	0.0340	0.0155				
	FD - 24 h	289.68	132.90	45.88	1	0.0290	0.0133	0.0140	0.0010	-	-
					2	0.0320	0.0147				
	FD - 48 h	262.51	118.90	45.29	1	0.0220	0.0100	0.0109	0.0013	-	-
					2	0.0260	0.0118				
	FD - 72 h	416.00	187.70	45.12	1	0.0150	0.0068	0.0065	0.0003	-	-
					2	0.0140	0.0063				
Control	BDBP	247.50	123.40	49.86	1	0.3640	0.1815	0.1770	0.0063	-	-
					2	0.3460	0.1725				
	BDAP	244.00	119.00	48.77	1	0.2960	0.1444	0.1436	0.0010	-	-
					2	0.2930	0.1429				
RS	BDBP	265.50	129.00	48.59	1	0.1300	0.0632	0.0622	0.0014	-	-
					2	0.1260	0.0612				
	BDAP	239.00	117.60	49.21	1	0.1160	0.0571	0.0561	0.0014	-	-
					2	0.1120	0.0551				

Sample		Weight before freeze dry (g)	Weight after freeze dry (g)	Dry (%)	Replication	Total fructan (g/100g dry)	Total fructan (g/100g wet)	Mean (g/100g wet)	SD	Serve size (g)	Total fructan (g/per serve)
RS/RK	BDBP	250.60	121.36	48.43	1	0.1290	0.0625	0.0632	0.0010	-	-
					2	0.1320	0.0639				
	BDAP	259.50	125.84	48.49	1	0.1260	0.0611	0.0621	0.0014	-	-
					2	0.1300	0.0630				
RS/ISD	BDBP	260.00	126.82	48.78	1	0.2060	0.1005	0.0997	0.0010	-	-
					2	0.2030	0.0990				
	BDAP	261.60	128.36	49.07	1	0.1840	0.0903	0.0920	0.0024	-	-
					2	0.1910	0.0937				
Control/RP	BDBP	266.90	126.13	47.26	1	0.3620	0.1711	0.1685	0.0037	-	-
					2	0.3510	0.1659				
	BDAP	269.00	129.00	47.96	1	0.3480	0.1669	0.1652	0.0024	-	-
					2	0.3410	0.1635				
Control	Bread	500.18	292.54	58.49	1	0.2280	0.1334	0.1310	0.0033	73	0.0956
					2	0.2200	0.1287				
RS	Bread	501.32	290.24	57.90	1	0.1210	0.0701	0.0657	0.0061	73	0.0480
					2	0.1060	0.0614				
RS/RK	Bread	500.52	289.14	57.77	1	0.1230	0.0711	0.0687	0.0033	73	0.0502
					2	0.1150	0.0664				
RS/ISD	Bread	500.14	284.51	56.89	1	0.1370	0.0779	0.0779	0.0000	73	0.0569
					2	0.1370	0.0779				
Control/RP	Bread	500.03	280.55	56.11	1	0.1840	0.1032	0.1010	0.0032	73	0.0737
					2	0.1760	0.0987				

Table C.7 Raw data of loaf weight, loaf volume, specific volume, baking weight loss, and water activity (Day 0 and Day 7) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes (n = 3)

Sample	Loaf weight (g)					Loaf volume (cm ³)				
	Replication			Mean	SD	Replication			Mean	SD
	1	2	3			1	2	3		
Control	536	534	534	534.67	1.15	1240.00	1230.00	1240.00	1236.67	5.77
RS	538	542	536	538.67	3.06	1310.00	1310.00	1320.00	1313.33	5.77
RS/RK	525	526	526	525.67	0.58	1180.00	1170.00	1175.00	1175.00	5.00
RS/ISD	536	532	535	534.33	2.08	1330.00	1320.00	1330.00	1326.67	5.77
Control/RP	566	566	563	565.00	1.73	1240.00	1250.00	1235.00	1241.67	7.64
Sample	Specific volume (cm ³ /g)					Baking weight loss (%)				
	Replication			Mean	SD	Replication			Mean	SD
	1	2	3			1	2	3		
Control	2.31	2.30	2.32	2.31	0.01	13.55	13.87	13.87	13.76	0.19
RS	2.43	2.42	2.46	2.44	0.02	13.23	12.58	13.55	13.12	0.49
RS/RK	2.25	2.22	2.23	2.24	0.01	15.32	15.16	15.16	15.22	0.09
RS/ISD	2.48	2.48	2.49	2.48	0.00	13.55	14.19	13.71	13.82	0.34
Control/RP	2.19	2.21	2.19	2.20	0.01	8.71	8.71	9.19	8.87	0.28
Sample	Water activity (Day 0)					Water activity (Day 7)				
	Replication			Mean	SD	Replication			Mean	SD
	1	2	3			1	2	3		
Control	0.98	0.98	0.98	0.9781	0.0025	0.9784	0.9722	0.9710	0.9739	0.0040
RS	0.98	0.98	0.98	0.9790	0.0017	0.9810	0.9778	0.9798	0.9795	0.0016
RS/RK	0.98	0.98	0.98	0.9810	0.0007	0.9847	0.9837	0.9839	0.9841	0.0005
RS/ISD	0.98	0.98	0.98	0.9817	0.0010	0.9810	0.9819	0.9804	0.9811	0.0008
Control/RP	0.98	0.98	0.98	0.9787	0.0031	0.9766	0.9781	0.9769	0.9772	0.0008

Table C.8 Raw data of texture profile analysis (TPA) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes (n = 12)

Sample	Replication	Texture profile analysis (TPA)					
		Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness (N)	Resilience
Control	1	16.04	0.95	0.58	9.31	8.89	0.26
	2	13.78	0.95	0.59	8.09	7.73	0.26
	3	15.17	0.90	0.62	9.46	8.52	0.23
	4	20.91	0.95	0.51	10.57	10.09	0.21
	5	17.36	0.94	0.53	9.27	8.75	0.22
	6	18.39	0.95	0.52	9.58	9.11	0.22
	7	12.60	0.95	0.55	6.99	6.67	0.25
	8	14.14	0.94	0.51	7.25	6.78	0.20
	9	13.46	0.96	0.60	8.07	7.76	0.29
	10	17.04	0.96	0.57	9.76	9.34	0.25
	11	21.41	0.96	0.57	12.11	11.65	0.26
	12	15.32	0.97	0.59	8.97	8.67	0.28
	Mean	16.30	0.95	0.56	9.12	8.66	0.24
	SD	2.83	0.02	0.04	1.42	1.38	0.03
Coef. of Variation	17.39	1.86	6.57	15.53	15.91	11.06	
RS	1	14.09	0.94	0.56	7.91	7.44	0.24
	2	13.17	0.95	0.62	8.21	7.84	0.29
	3	9.96	0.96	0.67	6.68	6.40	0.32
	4	12.04	0.96	0.66	7.89	7.61	0.30
	5	14.43	0.95	0.56	8.11	7.74	0.24
	6	13.52	0.95	0.58	7.80	7.43	0.26
	7	15.79	0.96	0.57	8.96	8.60	0.26
	8	13.60	0.97	0.60	8.17	7.88	0.28
	9	13.62	0.96	0.57	7.80	7.51	0.26
	10	14.42	0.95	0.55	7.90	7.53	0.24
	11	19.12	0.96	0.52	9.88	9.53	0.23
	12	16.30	0.96	0.53	8.59	8.26	0.24
	Mean	14.17	0.96	0.58	8.16	7.81	0.26
	SD	2.26	0.01	0.05	0.76	0.75	0.03
Coef. of Variation	15.93	0.74	8.19	9.37	9.66	10.79	
RS/RK	1	22.03	0.95	0.54	11.91	11.32	0.24
	2	19.44	0.94	0.55	10.78	10.17	0.23
	3	14.86	0.94	0.59	8.82	8.30	0.27
	4	16.83	0.96	0.58	9.82	9.39	0.27
	5	14.78	0.94	0.59	8.71	8.21	0.27
	6	13.85	0.93	0.61	8.48	7.86	0.27
	7	17.16	0.94	0.60	10.26	9.67	0.25
	8	16.18	0.95	0.62	10.10	9.57	0.26
	9	20.15	0.94	0.59	11.87	11.18	0.26
	10	20.59	0.94	0.57	11.63	10.89	0.24
	11	14.47	0.95	0.73	10.51	9.93	0.31
	12	15.57	0.96	0.64	9.92	9.49	0.30
	Mean	17.16	0.94	0.60	10.23	9.67	0.26
	SD	2.74	0.01	0.05	1.19	1.14	0.02
Coef. of Variation	15.95	0.89	8.01	11.59	11.77	8.61	

Sample	Replication	Texture profile analysis (TPA)					
		Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness (N)	Resilience
RS/ISD	1	17.76	0.93	0.50	8.84	8.20	0.18
	2	16.01	0.91	0.54	8.65	7.87	0.19
	3	16.47	0.92	0.53	8.81	8.10	0.20
	4	15.00	0.93	0.56	8.42	7.85	0.23
	5	15.78	0.92	0.51	7.99	7.33	0.18
	6	18.20	0.90	0.53	9.59	8.66	0.18
	7	17.58	0.91	0.52	9.21	8.35	0.17
	8	15.97	0.91	0.53	8.53	7.74	0.18
	9	18.71	0.89	0.48	8.95	7.98	0.14
	10	17.84	0.89	0.51	9.17	8.13	0.16
	11	16.04	0.91	0.58	9.22	8.36	0.20
	12	14.91	0.91	0.58	8.60	7.84	0.21
	Mean	16.69	0.91	0.53	8.83	8.04	0.18
	SD	1.28	0.01	0.03	0.43	0.35	0.02
Coef. of Variation	7.65	1.44	5.66	4.89	4.31	12.25	
Control/RP	1	13.22	0.94	0.65	8.65	8.11	0.29
	2	13.35	0.93	0.64	8.58	8.01	0.28
	3	9.88	0.95	0.71	6.98	6.64	0.33
	4	12.75	0.96	0.75	9.60	9.25	0.34
	5	15.10	0.94	0.63	9.51	8.95	0.28
	6	12.89	0.94	0.64	8.29	7.81	0.28
	7	13.27	0.94	0.62	8.26	7.80	0.28
	8	10.35	0.95	0.71	7.36	7.01	0.33
	9	12.10	0.96	0.74	9.01	8.65	0.34
	10	13.45	0.95	0.59	7.88	7.52	0.27
	11	14.94	0.95	0.59	8.88	8.47	0.26
	12	13.33	0.95	0.68	9.01	8.58	0.30
	Mean	12.89	0.95	0.66	8.50	8.06	0.30
	SD	1.54	0.01	0.06	0.80	0.77	0.03
Coef. of Variation	11.97	0.96	8.30	9.38	9.57	10.10	

Table C.9 Raw data of crumb and crust colour parameters (L* - lightness, a* - redness and b* - yellowness) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes (n = 9)

Sample		Replication	Crumb colour			Crust colour		
			Colour (L* - lightness)	Colour (a* - redness)	Colour (b* - yellowness)	Colour (L* - lightness)	Colour (a* - redness)	Colour (b* - yellowness)
Control	Bread 1	1	64.96	2.04	20.07	51.74	9.57	25.38
		2	65.23	2.14	19.47	52.35	9.92	25.79
		3	64.27	2.56	20.73	52.38	9.79	26.99
	Bread 2	1	64.83	2.01	19.47	50.78	10.81	26.65
		2	64.27	2.56	20.73	51.54	10.04	26.94
		3	64.83	2.01	19.47	50.03	10.92	26.13
	Bread 3	1	66.25	2.59	19.42	52.86	9.81	25.95
		2	66.16	2.58	19.45	52.88	9.63	25.80
		3	66.07	2.59	19.47	51.82	10.27	26.74
RS	Bread 1	1	69.68	-0.70	14.67	57.61	10.28	27.43
		2	69.61	-0.70	14.75	57.57	10.29	27.64
		3	70.54	-0.82	14.99	57.52	10.29	27.72
	Bread 2	1	69.48	-0.88	14.27	56.29	10.64	26.64
		2	69.48	-0.90	14.29	56.29	10.66	26.67
		3	73.38	-0.47	11.97	56.29	10.66	26.70
	Bread 3	1	72.47	-0.45	12.01	56.11	10.78	26.56
		2	72.28	-0.44	12.04	57.51	10.00	27.75
		3	72.19	-0.44	12.04	57.76	10.88	27.05
RS/RK	Bread 1	1	70.24	-0.20	12.17	57.89	7.18	26.76
		2	70.19	-0.23	12.23	57.99	7.22	26.92
		3	70.12	-0.21	12.24	57.78	7.10	26.74
	Bread 2	1	70.07	-0.22	12.26	56.72	9.52	26.34
		2	70.02	-0.21	12.26	56.68	9.58	26.45
		3	69.98	-0.21	12.26	56.65	9.60	26.49
	Bread 3	1	69.95	-0.22	12.26	58.45	6.47	26.02
		2	69.93	-0.23	12.26	58.45	6.48	26.06
		3	69.90	-0.22	12.25	58.41	6.45	25.93
RS/ISD	Bread 1	1	65.68	-0.27	10.68	46.96	7.88	19.12
		2	65.95	-0.34	10.85	46.35	7.98	19.48
		3	65.98	-0.33	10.91	47.34	8.02	19.48
	Bread 2	1	65.98	-0.36	10.99	47.36	8.02	19.50
		2	65.99	-0.35	11.02	47.40	8.01	19.52
		3	65.98	-0.34	11.02	47.35	8.02	19.45
	Bread 3	1	65.98	-0.34	11.06	45.88	12.67	22.02
		2	65.60	-0.04	10.55	45.69	12.71	22.10
		3	65.28	-0.10	10.59	45.54	12.75	22.15
Control/RP	Bread 1	1	64.72	2.14	18.21	50.87	9.36	21.52
		2	64.30	2.08	18.49	50.73	9.48	21.95
		3	64.11	2.09	18.58	50.68	9.50	21.97
	Bread 2	1	64.03	2.09	18.61	50.63	9.51	22.00
		2	63.97	2.07	18.63	50.59	9.52	22.02
		3	63.93	2.04	18.65	50.48	9.55	22.08
	Bread 3	1	63.81	2.09	18.68	50.43	9.57	22.10
		2	63.74	2.09	18.68	50.41	9.59	22.09
		3	63.71	2.08	18.70	50.39	9.59	22.09

Table C.10 Raw data of mean sensory attribute scores of baked GF sweet potato sourdough breads made using different formulations and fermentation processes (n = 50)

Sample	Panelist	Sensory attribute scores					Sample	Panelist	Sensory attribute scores				
		Appearance	Texture	Aroma	Taste	Overall Acceptability			Appearance	Texture	Aroma	Taste	Overall Acceptability
Control	1	7	6	8	7	7	Control	27	8	6	6	6	6
	2	7	6	3	7	7		28	7	7	5	6	7
	3	9	9	5	7	8		29	6	4	7	5	6
	4	8	6	7	8	7		30	7	7	6	7	7
	5	8	7	7	8	8		31	6	6	6	6	6
	6	8	7	6	7	7		32	8	6	7	6	6
	7	8	7	6	8	7		33	6	6	5	5	7
	8	7	7	8	9	9		34	8	7	4	7	7
	9	7	7	5	7	7		35	6	5	4	6	5
	10	7	8	5	8	8		36	7	7	5	5	5
	11	8	6	5	8	7		37	7	6	5	6	6
	12	7	6	7	6	6		38	9	7	8	5	6
	13	7	7	3	7	6		39	8	8	5	8	8
	14	7	7	8	7	8		40	6	7	7	8	6.5
	15	6	6	5	6	6		41	6	5	4	6	6
	16	7	6	6	7	8		42	5	7	4	4	5
	17	6	7	7	7	7		43	6	6	7	6	6
	18	7	7	6	5	6		44	7	7	3	5	5
	19	6	7	5	7	7		45	7	7	6	7	7
	20	4	4	5	3	4		46	7	4	6	6	7
	21	8	7	7	5	6		47	8	7	4	6	7
	22	7	7	7	8	8		48	6.5	7.5	7.5	7	7
	23	7	6	6	7	7		49	6	6	5	7	6
	24	3	6	5	4	4		50	7	8	5	8	7
	25	7	6	8	7	7		Mean	6.87	6.51	5.73	6.48	6.59
	26	6	7	5	6	6		SD	1.10	0.98	1.37	1.23	1.03

Sample	Panelist	Sensory attribute scores					Sample	Panelist	Sensory attribute scores				
		Appearance	Texture	Aroma	Taste	Overall Acceptability			Appearance	Texture	Aroma	Taste	Overall Acceptability
RS	1	7	7	7	4	5	RS	27	8	7	7	7	7
	2	8	6	5	4	7		28	5	6	6	7	7
	3	9	6	7	5	7		29	5	4	5	6	6
	4	8	6	5	4	5		30	7	7	6	6	6
	5	8	8	7	9	8		31	5	6	6	7	7
	6	7	6	7	8	7		32	9	7	5	7	7
	7	8	8	7	9	8		33	7	7	9	8	6
	8	7	8	6	8	8		34	7	7	5	7	7
	9	6	6	5	4	5		35	7	7	4	5	5
	10	9	9	6	9	9		36	8	8	5	7	6
	11	8	7	3	8	8		37	5	7	4	4	5
	12	8	8	5	7	7		38	8	6	7	5	5
	13	6	4	3	3	6		39	8	7	5	6	7
	14	6	7	6	5	7		40	8	8	7	7	7.5
	15	5	5	4	4	4		41	7	5	4	6	5
	16	6	7	5	6	6		42	8	7	4	5	6
	17	7	7	7	7	7		43	7	7	5	5	6
	18	7	7	5	8	7		44	7	7	4	5	5
	19	7	7	6	7	6		45	8	8	8	7	8
	20	7	7	5	5	6		46	6	6	5	6	6
	21	4	5	5	4	4		47	7	8	6	4	5
	22	5	6	6	5	6		48	8	7.5	5	5	5
	23	8	8	7	8	8		49	7	1	3	4	3
	24	7	6	6	6	6		50	7	8	5	7	7
	25	5	8	5	4	5		Mean	6.94	6.71	5.54	6.02	6.27
	26	5	8	7	7	7		SD	1.22	1.35	1.30	1.58	1.23

Sample	Panelist	Sensory attribute scores					Sample	Panelist	Sensory attribute scores				
		Appearance	Texture	Aroma	Taste	Overall Acceptability			Appearance	Texture	Aroma	Taste	Overall Acceptability
RS/RK	1	7	6	7	4	4	RS/RK	27	7	6	6	6	6
	2	8	6	4	6	7		28	7	9	7	6	7
	3	7	7	7	4	6		29	5	6	5	6	6
	4	8	4	5	5	6		30	6	6	5	6	6
	5	8	6	7	8	8		31	5	4	5	6	6
	6	5	5	5	5	5		32	7	4	4	5	6
	7	7	6	6	7	7		33	8	8	8	8	8
	8	8	5	5	6	6		34	7	8	7	7	8
	9	4	4	3	4	4		35	8	8	4	4	3
	10	8	7	5	9	8		36	8	8	6	7	7
	11	7	4	2	3	4		37	5	4	5	5	5
	12	8	6	5	9	7		38	9	8	8	7	5
	13	5	3	3	3	4		39	8	7	5	6	6
	14	5	7	6	6	7		40	7.5	6	7	7	6.5
	15	6	6	5	5	5		41	5	4	4	5	5
	16	6	5	5	4	4		42	4	4	4	4	3
	17	7	6	6	7	6		43	7	7	6	7	7
	18	7	7	6	5	6		44	7	7	4	5	5
	19	8	8	6	6	6		45	8	7	6	6	7
	20	7	6	7	5	6		46	6	7	7	8	7
	21	6	3	4	4	3		47	9	6	6	6	6
	22	5	4	5	3	3		48	8	6	5	5	6
	23	8	8	7	7	7		49	8	9	4	6	7
	24	6	4	5	6	5		50	7	8	5	6	6
	25	5	7	7	5	5		Mean	6.79	6.02	5.46	5.70	5.77
	26	7	4	7	5	5		SD	1.29	1.60	1.33	1.43	1.35

Sample	Panelist	Sensory attribute scores					Sample	Panelist	Sensory attribute scores				
		Appearance	Texture	Aroma	Taste	Overall Acceptability			Appearance	Texture	Aroma	Taste	Overall Acceptability
RS/ISD	1	7	6	5	5	5	RS/ISD	27	5	5	5	5	5
	2	7	6	5	7	6		28	7	9	7	8	8
	3	8	7	9	8	8		29	5	4	5	5	5
	4	7	7	5	7	6		30	6	6	7	6	6
	5	8	6	7	5	7		31	7	7	6	7	7
	6	6	9	6	6	6		32	6	4	4	4	5
	7	7	8	6	8	8		33	5	4	8	6	6
	8	8	8	5	7	7		34	6	5	3	3	4
	9	5	5	4	4	5		35	8	8	5	6	6
	10	9	7	8	8	8		36	6	7	7	7	7
	11	8	8	5	8	8		37	5	4	5	5	5
	12	7	8	5	7	7		38	9	8	6	8	6
	13	5	7	5	6	6		39	4	4	5	5	4
	14	6	6	6	6	6		40	7	6.5	6.5	7	6.5
	15	6	6	6	5	6		41	4	3	3	6	5
	16	6	6	6	6	6		42	6	5	5	4	4
	17	7	7	6	6	6		43	6	7	6	6	6
	18	7	6	6	5	6		44	7	7	5	4	4
	19	8	8	7	6	7		45	8	7	7	6	7
	20	6	4	5	5	5		46	6	5	5	6	5.5
	21	4	4	5	3	4		47	8	6	6	3	5
	22	5	4	4	4	4		48	7	7	6	6	6
	23	8	6	7	8	7		49	7	9	6	2	2
	24	7	4	5	4	4		50	7	8	3	4	4
	25	4	4	5	4	3		Mean	6.50	6.19	5.63	5.68	5.74
	26	7	7	7	7	7		SD	1.28	1.59	1.25	1.53	1.37

Sample	Panelist	Sensory attribute scores					Sample	Panelist	Sensory attribute scores				
		Appearance	Texture	Aroma	Taste	Overall Acceptability			Appearance	Texture	Aroma	Taste	Overall Acceptability
Control/RP	1	7	8	8	9	8	Control/RP	27	7	7	7	8	8
	2	5	7	5	8	7		28	8	8	7	8	8
	3	8	7	9	5	7		29	7	7	6	7	6
	4	9	8	6	9	8		30	8	8	7	7	7
	5	8	9	8	8	8		31	7	7	7	8	8
	6	7	8	8	8	8		32	8	7	6	8	7
	7	8	8	8	8	8		33	3	7	7	7	5
	8	6	8	5	7	8		34	7	7	5	6	6
	9	6	6	7	7	7		35	8	8	5	8	7
	10	7	7	6	9	8		36	8	8	6	8	8
	11	6	8	5	8	8		37	7	7	6	8	8
	12	8	8	6	8	7		38	9	8	6	8	7
	13	5	5	8	8	8		39	8	8	6	7	7
	14	8	8	6	8	8		40	6	6	6.5	7	7
	15	7	7	7	7	8		41	7	6	3	7	6
	16	7	7	7	8	8		42	6	8	4	7	7
	17	6	8	7	8	8		43	6	7	8	8	8
	18	7	7	6	7	8		44	8	7	5	6	6
	19	7	7	6	8	8		45	8	8	6	7	7
	20	4	8	5	7	8		46	7	8	7.5	8	8
	21	7	6	7	6	7		47	8	7	6	9	7
	22	6	8	6	8	7		48	8	8	8	8	8
	23	8	9	7	8	9		49	7	9	4	9	8
	24	6	7	7	7	7		50	7	8	6	8	8
	25	8	8	9	8	8		Mean	7.02	7.48	6.44	7.64	7.48
	26	7	8	8	8	8		SD	1.17	0.81	1.27	0.83	0.76

D. Statistic Output

D.1 Statistical analysis of LAB and yeast counts of GF sourdough starter (SD) during 72 h propagation

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
SD_LAB	UD 0h	2	8.2899	.01575	.01114	8.1484	8.4314	8.28	8.30
	FD 24h	2	8.5854	.08351	.05905	7.8351	9.3357	8.53	8.64
	FD 48h	2	9.4266	.03563	.02519	9.1065	9.7467	9.40	9.45
	FD 72h	2	9.4502	.00871	.00616	9.3719	9.5285	9.44	9.46
	Total	8	8.9380	.54765	.19363	8.4802	9.3959	8.28	9.46
SD_Yeast	UD 0h	2	4.1505	.21286	.15051	2.2380	6.0630	4.00	4.30
	FD 24h	2	4.6505	.06853	.04846	4.0348	5.2662	4.60	4.70
	FD 48h	2	4.9978	.06162	.04358	4.4441	5.5515	4.95	5.04
	FD 72h	2	5.4393	.01117	.00790	5.3389	5.5396	5.43	5.45
	Total	8	4.8095	.51230	.18112	4.3812	5.2378	4.00	5.45

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SD_LAB	Between Groups	2.091	3	.697	325.417	.000
	Within Groups	.009	4	.002		
	Total	2.099	7			
SD_Yeast	Between Groups	1.783	3	.594	44.089	.002
	Within Groups	.054	4	.013		
	Total	1.837	7			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Sourdough	(J) Sourdough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SD_LAB	UD 0h	FD 24h	-.29550*	.04628	.011	-.4839	-.1071
		FD 48h	-1.13670*	.04628	.000	-1.3251	-.9483
		FD 72h	-1.16031*	.04628	.000	-1.3487	-.9719
	FD 24h	UD 0h	.29550*	.04628	.011	.1071	.4839
		FD 48h	-.84120*	.04628	.000	-1.0296	-.6528
		FD 72h	-.86482*	.04628	.000	-1.0532	-.6764
	FD 48h	UD 0h	1.13670*	.04628	.000	.9483	1.3251
		FD 24h	.84120*	.04628	.000	.6528	1.0296
		FD 72h	-.02361	.04628	.952	-.2120	.1648
	FD 72h	UD 0h	1.16031*	.04628	.000	.9719	1.3487
		FD 24h	.86482*	.04628	.000	.6764	1.0532
		FD 48h	.02361	.04628	.952	-.1648	.1210
SD_Yeast	UD 0h	FD 24h	-.50000*	.11611	.042	-.9727	-.0273
		FD 48h	-.84730*	.11611	.006	-1.3200	-.3746
		FD 72h	-1.28875*	.11611	.001	-1.7614	-.8161
	FD 24h	UD 0h	.50000*	.11611	.042	.0273	.9727
		FD 48h	-.34730	.11611	.125	-.8200	.1254
		FD 72h	-.78875*	.11611	.008	-1.2614	-.3161
	FD 48h	UD 0h	.84730*	.11611	.006	.3746	1.3200
		FD 24h	.34730	.11611	.125	-.1254	.8200
		FD 72h	-.44144	.11611	.062	-.9141	.0312
	FD 72h	UD 0h	1.28875*	.11611	.001	.8161	1.7614
		FD 24h	.78875*	.11611	.008	.3161	1.2614
		FD 48h	.44144	.11611	.062	-.0312	.9141

*. The mean difference is significant at the 0.05 level.

SD_LAB

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05		
		1	2	3
UD 0h	2	8.2899		
FD 24h	2		8.5854	
FD 48h	2			9.4266
FD 72h	2			9.4502
Sig.		1.000	1.000	.952

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Yeast

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05		
		1	2	3
UD 0h	2	4.1505		
FD 24h	2		4.6505	
FD 48h	2		4.9978	4.9978
FD 72h	2			5.4393
Sig.		1.000	.125	.062

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

D.2 Statistical analysis of pH and TTA of GF sourdough starter (SD) during 72 h propagation

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
SD_pH	UD 0h	3	5.6667	.02082	.01202	5.6150	5.7184	5.65	5.69
	FD 24h	3	4.1467	.01528	.00882	4.1087	4.1846	4.13	4.16
	FD 48h	3	4.0467	.01528	.00882	4.0087	4.0846	4.03	4.06
	FD 72h	3	3.8300	.11269	.06506	3.5501	4.1099	3.70	3.90
	Total	12	4.4225	.76135	.21978	3.9388	4.9062	3.70	5.69
SD_TTA	UD 0h	3	4.3500	.05000	.02887	4.2258	4.4742	4.30	4.40
	FD 24h	3	10.4433	.02887	.01667	10.3716	10.5150	10.41	10.46
	FD 48h	3	10.8767	.02887	.01667	10.8050	10.9484	10.86	10.91
	FD 72h	3	11.2100	.10000	.05774	10.9616	11.4584	11.11	11.31
	Total	12	9.2200	2.95085	.85184	7.3451	11.0949	4.30	11.31

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SD_pH	Between Groups	6.349	3	2.116	622.453	.000
	Within Groups	.027	8	.003		
	Total	6.376	11			
SD_TTA	Between Groups	95.754	3	31.918	9012.166	.000
	Within Groups	.028	8	.004		
	Total	95.783	11			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Sourdough	(J) Sourdough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SD_pH	UD 0h	FD 24h	1.52000*	.04761	.000	1.3675	1.6725
		FD 48h	1.62000*	.04761	.000	1.4675	1.7725
		FD 72h	1.83667*	.04761	.000	1.6842	1.9891
	FD 24h	UD 0h	-.52000*	.04761	.000	-1.6725	-1.3675
		FD 48h	.10000	.04761	.232	-.0525	.2525
		FD 72h	.31667*	.04761	.001	.1642	.4691
	FD 48h	UD 0h	-1.62000*	.04761	.000	-1.7725	-1.4675
		FD 24h	-.10000	.04761	.232	-.2525	.0525
		FD 72h	.21667*	.04761	.008	.0642	.3691
	FD 72h	UD 0h	-1.83667*	.04761	.000	-1.9891	-1.6842
		FD 24h	-.31667*	.04761	.001	-.4691	-.1642
		FD 48h	-.21667*	.04761	.008	-.3691	-.0642
SD_TTA	UD 0h	FD 24h	-6.09333*	.04859	.000	-6.2489	-5.9377
		FD 48h	-6.52667*	.04859	.000	-6.6823	-6.3711
		FD 72h	-6.86000*	.04859	.000	-7.0156	-6.7044
	FD 24h	UD 0h	6.09333*	.04859	.000	5.9377	6.2489
		FD 48h	-.43333*	.04859	.000	-.5889	-.2777
		FD 72h	-.76667*	.04859	.000	-.9223	-.6111
	FD 48h	UD 0h	6.52667*	.04859	.000	6.3711	6.6823
		FD 24h	.43333*	.04859	.000	.2777	.5889
		FD 72h	-.33333*	.04859	.001	-.4889	-.1777
	FD 72h	UD 0h	6.86000*	.04859	.000	6.7044	7.0156
		FD 24h	.76667*	.04859	.000	.6111	.9223
		FD 48h	.33333*	.04859	.001	.1777	.4889

*. The mean difference is significant at the 0.05 level.

SD_pH

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05		
		1	2	3
FD 72h	3	3.8300		
FD 48h	3		4.0467	
FD 24h	3		4.1467	
UD 0h	3			5.6667
Sig.		1.000	.232	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

SD_TTA

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05			
		1	2	3	4
UD 0h	3	4.3500			
FD 24h	3		10.4433		
FD 48h	3			10.8767	
FD 72h	3				11.2100
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

D.3 Statistical analysis of lactic and acetic acid concentration in GF sourdough starter (SD) during 72 h propagation

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
SD_Lacticacid	UD 0h	4	.1580	.00423	.00212	.1513	.1648	.15	.16
	FD 24h	4	.9231	.04905	.02452	.8450	1.0011	.89	1.00
	FD 48h	4	1.1733	.06570	.03285	1.0688	1.2779	1.11	1.24
	FD 72h	4	1.2250	.05165	.02582	1.1428	1.3071	1.16	1.27
	Total	16	.8698	.44265	.11066	.6340	1.1057	.15	1.27
SD_Aceticacid	UD 0h	4	.3375	.00821	.00410	.3244	.3505	.33	.35
	FD 24h	4	.4269	.00437	.00218	.4200	.4339	.42	.43
	FD 48h	4	.4483	.02439	.01220	.4095	.4871	.42	.47
	FD 72h	4	.4878	.05223	.02612	.4047	.5709	.44	.56
	Total	16	.4251	.06264	.01566	.3918	.4585	.33	.56

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SD_Lacticacid	Between Groups	2.911	3	.970	412.540	.000
	Within Groups	.028	12	.002		
	Total	2.939	15			
SD_Aceticacid	Between Groups	.049	3	.016	19.011	.000
	Within Groups	.010	12	.001		
	Total	.059	15			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Sourdough	(J) Sourdough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SD_Lacticacid	UD 0h	FD 24h	-.76505*	.03429	.000	-.8669	-.6632
		FD 48h	-1.01530*	.03429	.000	-1.1171	-.9135
		FD 72h	-1.06693*	.03429	.000	-1.1687	-.9651
	FD 24h	UD 0h	.76505*	.03429	.000	.6632	.8669
		FD 48h	-.25025*	.03429	.000	-.3521	-.1484
		FD 72h	-.30188*	.03429	.000	-.4037	-.2001
	FD 48h	UD 0h	1.01530*	.03429	.000	.9135	1.1171
		FD 24h	.25025*	.03429	.000	.1484	.3521
		FD 72h	-.05163	.03429	.464	-.1534	.0502
	FD 72h	UD 0h	1.06693*	.03429	.000	.9651	1.1687
		FD 24h	.30188*	.03429	.000	.2001	.4037
		FD 48h	.05163	.03429	.464	-.0502	.1534
SD_Aceticacid	UD 0h	FD 24h	-.08949*	.02065	.005	-.1508	-.0282
		FD 48h	-.11087*	.02065	.001	-.1722	-.0496
		FD 72h	-.15034*	.02065	.000	-.2116	-.0890
	FD 24h	UD 0h	.08949*	.02065	.005	.0282	.1508
		FD 48h	-.02138	.02065	.733	-.0827	.0399
		FD 72h	-.06085	.02065	.052	-.1221	.0004
	FD 48h	UD 0h	.11087*	.02065	.001	.0496	.1722
		FD 24h	.02138	.02065	.733	-.0399	.0827
		FD 72h	-.03947	.02065	.274	-.1008	.0218
	FD 72h	UD 0h	.15034*	.02065	.000	.0890	.2116
		FD 24h	.06085	.02065	.052	-.0004	.1221
		FD 48h	.03947	.02065	.274	-.0218	.1008

*. The mean difference is significant at the 0.05 level.

SD_Lacticacid

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05		
		1	2	3
UD 0h	4	.1580		
FD 24h	4		.9231	
FD 48h	4			1.1733
FD 72h	4			1.2250
Sig.		1.000	1.000	.464

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

SD_Aceticacid

Tukey HSD^a

Sourdough	N	Subset for alpha = 0.05	
		1	2
UD 0h	4	.3375	
FD 24h	4		.4269
FD 48h	4		.4483
FD 72h	4		.4878
Sig.		1.000	.052

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

D.4 Statistical analysis of FODMAP content of GF sourdough starter (SD) over 72 h propagation (g per 100 g as wet weight)

		Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
SD_Fructose	UD 0h	2	.0797	.00484	.00342	.0362	.1232	.08	.08
	FD 24h	2	.0070	.00002	.00001	.0069	.0072	.01	.01
	FD 48h	2	.0019	.00006	.00004	.0014	.0025	.00	.00
	FD 72h	2	.0013	.00007	.00005	.0008	.0019	.00	.00
	Total	8	.0225	.03545	.01253	-.0072	.0521	.00	.08
SD_Glucose	UD 0h	2	.0994	.00571	.00404	.0481	.1508	.10	.10
	FD 24h	2	.1064	.00126	.00089	.0950	.1177	.11	.11
	FD 48h	2	.1140	.00428	.00301	.0757	.1522	.11	.12
	FD 72h	2	.0884	.00240	.00169	.0469	.0899	.07	.07
	Total	8	.0970	.01875	.00863	.0814	.1127	.07	.12
SD_Excessfructose	UD 0h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 24h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 48h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 72h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	8	.0000	.00000	.00000	.0000	.0000	.00	.00
SD_Sorbitol	UD 0h	2	.0030	.00012	.00008	.0019	.0040	.00	.00
	FD 24h	2	.0042	.00008	.00006	.0035	.0049	.00	.00
	FD 48h	2	.0044	.00006	.00004	.0039	.0049	.00	.00
	FD 72h	2	.0062	.00011	.00008	.0052	.0072	.01	.01
	Total	8	.0044	.00122	.00043	.0034	.0055	.00	.01
SD_Mannitol	UD 0h	2	.0197	.00104	.00074	.0104	.0290	.02	.02
	FD 24h	2	.0322	.00021	.00015	.0303	.0340	.03	.03
	FD 48h	2	.0345	.00059	.00041	.0292	.0397	.03	.03
	FD 72h	2	.0335	.00056	.00039	.0285	.0385	.03	.03
	Total	8	.0300	.00641	.00227	.0246	.0353	.02	.03
SD_Raffinose	UD 0h	2	.0524	.00353	.00249	.0207	.0841	.05	.05
	FD 24h	2	.0176	.00009	.00007	.0168	.0184	.02	.02
	FD 48h	2	.0067	.00014	.00010	.0054	.0080	.01	.01
	FD 72h	2	.0025	.00011	.00008	.0015	.0034	.00	.00
	Total	8	.0198	.02103	.00743	.0022	.0374	.00	.05
SD_Stachyose	UD 0h	2	.0075	.00046	.00032	.0034	.0116	.01	.01
	FD 24h	2	.0319	.00033	.00023	.0290	.0349	.03	.03
	FD 48h	2	.0423	.00173	.00122	.0267	.0578	.04	.04
	FD 72h	2	.0205	.00042	.00030	.0167	.0242	.02	.02
	Total	8	.0256	.01387	.00490	.0140	.0371	.01	.04
SD_Nystose	UD 0h	2	.0262	.00117	.00083	.0158	.0367	.03	.03
	FD 24h	2	.0091	.00012	.00008	.0080	.0102	.01	.01
	FD 48h	2	.0105	.00041	.00029	.0068	.0142	.01	.01
	FD 72h	2	.0085	.00043	.00030	.0046	.0124	.01	.01
	Total	8	.0136	.00787	.00278	.0070	.0202	.01	.03
SD_Kestose	UD 0h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 24h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 48h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	FD 72h	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	8	.0000	.00000	.00000	.0000	.0000	.00	.00
SD_Totalfructan	UD 0h	2	.0164	.00129	.00091	.0048	.0280	.02	.02
	FD 24h	2	.0140	.00097	.00069	.0052	.0227	.01	.01
	FD 48h	2	.0109	.00128	.00091	-.0006	.0224	.01	.01
	FD 72h	2	.0065	.00032	.00023	.0037	.0094	.01	.01
	Total	8	.0120	.00403	.00143	.0086	.0153	.01	.02

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SD_Fructose	Between Groups	.009	3	.003	498.963	.000
	Within Groups	.000	4	.000		
	Total	.009	7			
SD_Glucose	Between Groups	.002	3	.001	55.133	.001
	Within Groups	.000	4	.000		
	Total	.002	7			
SD_Excessfructose	Between Groups	.000	3	.000		
	Within Groups	.000	4	.000		
	Total	.000	7			
SD_Sorbitol	Between Groups	.000	3	.000	382.624	.000
	Within Groups	.000	4	.000		
	Total	.000	7			
SD_Mannitol	Between Groups	.000	3	.000	214.252	.000
	Within Groups	.000	4	.000		
	Total	.000	7			
SD_Raffinose	Between Groups	.003	3	.001	329.084	.000
	Within Groups	.000	4	.000		
	Total	.003	7			
SD_Stachyose	Between Groups	.001	3	.000	513.252	.000
	Within Groups	.000	4	.000		
	Total	.001	7			
SD_Nystose	Between Groups	.000	3	.000	332.141	.000
	Within Groups	.000	4	.000		
	Total	.000	7			
SD_Kestose	Between Groups	.000	3	.000		
	Within Groups	.000	4	.000		
	Total	.000	7			
SD_Totalfructan	Between Groups	.000	3	.000	33.492	.003
	Within Groups	.000	4	.000		
	Total	.000	7			

SD_Fructose

		Subset for alpha = 0.05		
Sourdough	N	1	2	
Tukey HSD ^a	FD 72h	2	.0013	
	FD 48h	2	.0019	
	FD 24h	2	.0070	
	UD 0h	2		.0797
	Sig.		.223	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Glucose

		Subset for alpha = 0.05		
Sourdough	N	1	2	
Tukey HSD ^a	FD 72h	2	.0684	
	UD 0h	2		.0994
	FD 24h	2		.1064
	FD 48h	2		.1140
	Sig.		1.000	.061

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Sorbitol

		Subset for alpha = 0.05			
Sourdough	N	1	2	3	
Tukey HSD ^a	UD 0h	2	.0030		
	FD 24h	2		.0042	
	FD 48h	2		.0044	
	FD 72h	2			.0062
	Sig.		1.000	.197	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Mannitol

		Subset for alpha = 0.05		
Sourdough	N	1	2	
Tukey HSD ^a	UD 0h	2	.0197	
	FD 24h	2		.0322
	FD 72h	2		.0335
	FD 48h	2		.0345
	Sig.		1.000	.083

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Raffinose

		Subset for alpha = 0.05			
Sourdough	N	1	2	3	
Tukey HSD ^a	FD 72h	2	.0025		
	FD 48h	2	.0067		
	FD 24h	2		.0176	
	UD 0h	2			.0524
	Sig.		.221	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Stachyose

		Subset for alpha = 0.05				
Sourdough	N	1	2	3	4	
Tukey HSD ^a	UD 0h	2	.0075			
	FD 72h	2		.0205		
	FD 24h	2			.0319	
	FD 48h	2				.0423
	Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Nystose

		Subset for alpha = 0.05		
Sourdough	N	1	2	
Tukey HSD ^a	FD 72h	2	.0085	
	FD 24h	2	.0091	
	FD 48h	2	.0105	
	UD 0h	2		.0262
	Sig.		.115	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

SD_Totalfructan

		Subset for alpha = 0.05			
Sourdough	N	1	2	3	
Tukey HSD ^a	FD 72h	2	.0065		
	FD 48h	2		.0109	
	FD 24h	2		.0140	
	UD 0h	2			.0164
	Sig.		1.000	.125	.231

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Multiple Comparisons

Dependent Variable		(I) Sourdough	(J) Sourdough	Mean Difference	Std. Error	Sig.	95% Confidence Interval			
				(I-J)			Lower Bound	Upper Bound		
SD_Fructose	Tukey HSD	UD 0h	FD 24h	.07270'	.00242	.000	.0628	.0826		
			FD 48h	.07778'	.00242	.000	.0679	.0876		
			FD 72h	.07846'	.00242	.000	.0686	.0883		
		FD 24h	UD 0h	-.07270'	.00242	.000	-.0826	-.0628		
			FD 48h	.00508	.00242	.293	-.0048	.0149		
			FD 72h	.00577	.00242	.223	-.0041	.0156		
		FD 48h	UD 0h	-.07778'	.00242	.000	-.0876	-.0679		
			FD 24h	-.00508	.00242	.293	-.0149	.0048		
			FD 72h	.00068	.00242	.991	-.0092	.0105		
		FD 72h	UD 0h	-.07846'	.00242	.000	-.0883	-.0686		
			FD 24h	-.00577	.00242	.223	-.0156	.0041		
			FD 48h	-.00068	.00242	.991	-.0105	.0092		
		LSD	UD 0h	FD 24h	.07270'	.00242	.000	.0660	.0794	
				FD 48h	.07778'	.00242	.000	.0711	.0845	
				FD 72h	.07846'	.00242	.000	.0717	.0852	
			FD 24h	UD 0h	-.07270'	.00242	.000	-.0794	-.0660	
				FD 48h	.00508	.00242	.104	-.0016	.0118	
				FD 72h	.00577	.00242	.076	-.0010	.0125	
	FD 48h		UD 0h	-.07778'	.00242	.000	-.0845	-.0711		
			FD 24h	-.00508	.00242	.104	-.0118	.0016		
			FD 72h	.00068	.00242	.791	-.0080	.0074		
	FD 72h		UD 0h	-.07846'	.00242	.000	-.0852	-.0717		
			FD 24h	-.00577	.00242	.076	-.0125	.0010		
			FD 48h	-.00068	.00242	.791	-.0074	.0080		
	SD_Glucose		Tukey HSD	UD 0h	FD 24h	-.00691	.00381	.384	-.0224	.0086
					FD 48h	-.01454	.00381	.081	-.0301	.0010
					FD 72h	.03108'	.00381	.004	.0155	.0466
				FD 24h	UD 0h	.00691	.00381	.384	-.0086	.0224
					FD 48h	-.00763	.00381	.321	-.0231	.0079
					FD 72h	.03797'	.00381	.002	.0225	.0535
		FD 48h		UD 0h	.01454	.00381	.081	-.0010	.0301	
				FD 24h	.00763	.00381	.321	-.0079	.0231	
				FD 72h	.04560'	.00381	.001	.0301	.0611	
		FD 72h		UD 0h	-.03108'	.00381	.004	-.0466	-.0155	
				FD 24h	-.03797'	.00381	.002	-.0535	-.0225	
				FD 48h	-.04560'	.00381	.001	-.0611	-.0301	
LSD		UD 0h		FD 24h	-.00691	.00381	.144	-.0175	.0037	
				FD 48h	-.01454'	.00381	.019	-.0251	-.0040	
				FD 72h	.03108'	.00381	.001	.0205	.0416	
		FD 24h		UD 0h	.00691	.00381	.144	-.0037	.0175	
				FD 48h	-.00763	.00381	.116	-.0182	.0030	
				FD 72h	.03797'	.00381	.001	.0274	.0486	
	FD 48h	UD 0h	.01454'	.00381	.019	.0040	.0251			
		FD 24h	.00763	.00381	.116	-.0030	.0182			
		FD 72h	.04560'	.00381	.000	.0350	.0562			
	FD 72h	UD 0h	-.03108'	.00381	.001	-.0416	-.0205			
		FD 24h	-.03797'	.00381	.001	-.0486	-.0274			
		FD 48h	-.04560'	.00381	.000	-.0562	-.0350			
	SD_Sorbitol	Tukey HSD	UD 0h	FD 24h	-.00123'	.00010	.001	-.0016	-.0008	
				FD 48h	-.00147'	.00010	.000	-.0019	-.0011	
				FD 72h	-.00321'	.00010	.000	-.0036	-.0028	
			FD 24h	UD 0h	.00123'	.00010	.001	.0008	.0016	
				FD 48h	-.00024	.00010	.197	-.0006	.0001	
				FD 72h	-.00198'	.00010	.000	-.0024	-.0016	
FD 48h			UD 0h	.00147'	.00010	.000	.0011	.0019		
			FD 24h	.00024	.00010	.197	-.0001	.0006		
			FD 72h	-.00174'	.00010	.000	-.0021	-.0013		
FD 72h			UD 0h	.00321'	.00010	.000	.0028	.0036		
			FD 24h	.00198'	.00010	.000	.0016	.0024		
			FD 48h	.00174'	.00010	.000	.0013	.0021		
LSD			UD 0h	FD 24h	-.00123'	.00010	.000	-.0015	-.0010	
				FD 48h	-.00147'	.00010	.000	-.0017	-.0012	
				FD 72h	-.00321'	.00010	.000	-.0035	-.0029	
			FD 24h	UD 0h	.00123'	.00010	.000	.0010	.0015	

			FD 48h			-0.0024	.00010	.066		-0.0005	.0000
			FD 72h			-0.00198 [†]	.00010	.000		-0.0022	-.0017
		FD 48h	UD 0h			.00147 [†]	.00010	.000		.0012	.0017
			FD 24h			.00024	.00010	.066		.0000	.0005
			FD 72h			-0.00174 [†]	.00010	.000		-0.0020	-.0015
		FD 72h	UD 0h			.00321 [†]	.00010	.000		.0029	.0035
			FD 24h			.00198 [†]	.00010	.000		.0017	.0022
			FD 48h			.00174 [†]	.00010	.000		.0015	.0020
SD_Mannitol	Tukey HSD	UD 0h	FD 24h			-.01247 [†]	.00067	.000		-.0152	-.0098
			FD 48h			-.01477 [†]	.00067	.000		-.0175	-.0121
			FD 72h			-.01379 [†]	.00067	.000		-.0165	-.0111
		FD 24h	UD 0h			.01247 [†]	.00067	.000		.0098	.0152
			FD 48h			-.00230	.00067	.083		-.0050	.0004
			FD 72h			-.00132	.00067	.328		-.0040	.0014
		FD 48h	UD 0h			.01477 [†]	.00067	.000		.0121	.0175
			FD 24h			.00230	.00067	.083		-.0004	.0050
			FD 72h			.00098	.00067	.525		-.0017	.0037
		FD 72h	UD 0h			.01379 [†]	.00067	.000		.0111	.0165
			FD 24h			.00132	.00067	.328		-.0014	.0040
			FD 48h			-.00098	.00067	.525		-.0037	.0017
	LSD	UD 0h	FD 24h			-.01247 [†]	.00067	.000		-.0143	-.0106
			FD 48h			-.01477 [†]	.00067	.000		-.0166	-.0129
			FD 72h			-.01379 [†]	.00067	.000		-.0156	-.0119
		FD 24h	UD 0h			.01247 [†]	.00067	.000		.0106	.0143
			FD 48h			-.00230 [†]	.00067	.026		-.0042	-.0005
			FD 72h			-.00132	.00067	.119		-.0032	.0005
		FD 48h	UD 0h			.01477 [†]	.00067	.000		.0129	.0166
			FD 24h			.00230 [†]	.00067	.026		.0005	.0042
			FD 72h			.00098	.00067	.215		-.0009	.0028
		FD 72h	UD 0h			.01379 [†]	.00067	.000		.0119	.0156
			FD 24h			.00132	.00067	.119		-.0005	.0032
			FD 48h			-.00098	.00067	.215		-.0028	.0009
SD_Raffinose	Tukey HSD	UD 0h	FD 24h			.03479 [†]	.00177	.000		.0276	.0420
			FD 48h			.04573 [†]	.00177	.000		.0385	.0529
			FD 72h			.04995 [†]	.00177	.000		.0428	.0571
		FD 24h	UD 0h			-.03479 [†]	.00177	.000		-.0420	-.0276
			FD 48h			.01094 [†]	.00177	.012		.0037	.0181
			FD 72h			.01516 [†]	.00177	.004		.0080	.0224
		FD 48h	UD 0h			-.04573 [†]	.00177	.000		-.0529	-.0385
			FD 24h			-.01094 [†]	.00177	.012		-.0181	-.0037
			FD 72h			.00422	.00177	.221		-.0030	.0114
		FD 72h	UD 0h			-.04995 [†]	.00177	.000		-.0571	-.0428
			FD 24h			-.01516 [†]	.00177	.004		-.0224	-.0080
			FD 48h			-.00422	.00177	.221		-.0114	.0030
	LSD	UD 0h	FD 24h			.03479 [†]	.00177	.000		.0299	.0397
			FD 48h			.04573 [†]	.00177	.000		.0408	.0506
			FD 72h			.04995 [†]	.00177	.000		.0450	.0549
		FD 24h	UD 0h			-.03479 [†]	.00177	.000		-.0397	-.0299
			FD 48h			.01094 [†]	.00177	.003		.0060	.0158
			FD 72h			.01516 [†]	.00177	.001		.0103	.0201
		FD 48h	UD 0h			-.04573 [†]	.00177	.000		-.0506	-.0408
			FD 24h			-.01094 [†]	.00177	.003		-.0158	-.0060
			FD 72h			.00422	.00177	.075		-.0007	.0091
		FD 72h	UD 0h			-.04995 [†]	.00177	.000		-.0549	-.0450
			FD 24h			-.01516 [†]	.00177	.001		-.0201	-.0103
			FD 48h			-.00422	.00177	.075		-.0091	.0007
SD_Stachyose	Tukey HSD	UD 0h	FD 24h			-.02439 [†]	.00093	.000		-.0282	-.0206
			FD 48h			-.03475 [†]	.00093	.000		-.0386	-.0310
			FD 72h			-.01292 [†]	.00093	.001		-.0167	-.0091
		FD 24h	UD 0h			.02439 [†]	.00093	.000		.0206	.0282
			FD 48h			-.01036 [†]	.00093	.001		-.0142	-.0066
			FD 72h			.01148 [†]	.00093	.001		.0077	.0153
		FD 48h	UD 0h			.03475 [†]	.00093	.000		.0310	.0386
			FD 24h			.01036 [†]	.00093	.001		.0066	.0142
			FD 72h			.02184 [†]	.00093	.000		.0180	.0256
		FD 72h	UD 0h			.01292 [†]	.00093	.001		.0091	.0167
			FD 24h			-.01148 [†]	.00093	.001		-.0153	-.0077
			FD 48h			-.02184 [†]	.00093	.000		-.0256	-.0180
	LSD	UD 0h	FD 24h			-.02439 [†]	.00093	.000		-.0270	-.0218

			FD 48h	-.03475*	.00093	.000	-.0373	-.0322
			FD 72h	-.01292*	.00093	.000	-.0155	-.0103
		FD 24h	UD 0h	.02439*	.00093	.000	.0218	.0270
			FD 48h	-.01036*	.00093	.000	-.0130	-.0078
			FD 72h	.01148*	.00093	.000	.0089	.0141
		FD 48h	UD 0h	.03475*	.00093	.000	.0322	.0373
			FD 24h	.01036*	.00093	.000	.0078	.0130
			FD 72h	.02184*	.00093	.000	.0192	.0244
		FD 72h	UD 0h	.01292*	.00093	.000	.0103	.0155
			FD 24h	-.01148*	.00093	.000	-.0141	-.0089
			FD 48h	-.02184*	.00093	.000	-.0244	-.0192
SD_Nystose	Tukey HSD	UD 0h	FD 24h	.01717*	.00066	.000	.0145	.0199
			FD 48h	.01572*	.00066	.000	.0130	.0184
			FD 72h	.01775*	.00066	.000	.0151	.0204
		FD 24h	UD 0h	-.01717*	.00066	.000	-.0199	-.0145
			FD 48h	-.00145	.00066	.285	-.0041	.0012
			FD 72h	.00058	.00066	.815	-.0021	.0033
		FD 48h	UD 0h	-.01572*	.00066	.000	-.0184	-.0130
			FD 24h	.00145	.00066	.285	-.0012	.0041
			FD 72h	.00203	.00066	.115	-.0007	.0047
		FD 72h	UD 0h	-.01775*	.00066	.000	-.0204	-.0151
			FD 24h	-.00058	.00066	.815	-.0033	.0021
			FD 48h	-.00203	.00066	.115	-.0047	.0007
	LSD	UD 0h	FD 24h	.01717*	.00066	.000	.0153	.0190
			FD 48h	.01572*	.00066	.000	.0139	.0176
			FD 72h	.01775*	.00066	.000	.0159	.0196
		FD 24h	UD 0h	-.01717*	.00066	.000	-.0190	-.0153
			FD 48h	-.00145	.00066	.093	-.0033	.0004
			FD 72h	.00058	.00066	.427	-.0012	.0024
		FD 48h	UD 0h	-.01572*	.00066	.000	-.0176	-.0139
			FD 24h	.00145	.00066	.093	-.0004	.0033
			FD 72h	.00203*	.00066	.037	.0002	.0039
		FD 72h	UD 0h	-.01775*	.00066	.000	-.0196	-.0159
			FD 24h	-.00058	.00066	.427	-.0024	.0012
			FD 48h	-.00203*	.00066	.037	-.0039	-.0002
SD_Totalfructan	Tukey HSD	UD 0h	FD 24h	.00245	.00104	.231	-.0018	.0067
			FD 48h	.00557*	.00104	.020	.0013	.0098
			FD 72h	.00990*	.00104	.002	.0056	.0141
		FD 24h	UD 0h	-.00245	.00104	.231	-.0067	.0018
			FD 48h	.00312	.00104	.125	-.0011	.0074
			FD 72h	.00745*	.00104	.007	.0032	.0117
		FD 48h	UD 0h	-.00557*	.00104	.020	-.0098	-.0013
			FD 24h	-.00312	.00104	.125	-.0074	.0011
			FD 72h	.00433*	.00104	.047	.0001	.0088
		FD 72h	UD 0h	-.00990*	.00104	.002	-.0141	-.0056
			FD 24h	-.00745*	.00104	.007	-.0117	-.0032
			FD 48h	-.00433*	.00104	.047	-.0088	-.0001
	LSD	UD 0h	FD 24h	.00245	.00104	.079	-.0005	.0053
			FD 48h	.00557*	.00104	.006	.0027	.0085
			FD 72h	.00990*	.00104	.001	.0070	.0128
		FD 24h	UD 0h	-.00245	.00104	.079	-.0053	.0005
			FD 48h	.00312*	.00104	.040	.0002	.0060
			FD 72h	.00745*	.00104	.002	.0046	.0103
		FD 48h	UD 0h	-.00557*	.00104	.006	-.0085	-.0027
			FD 24h	-.00312*	.00104	.040	-.0060	-.0002
			FD 72h	.00433*	.00104	.014	.0014	.0072
		FD 72h	UD 0h	-.00990*	.00104	.001	-.0128	-.0070
			FD 24h	-.00745*	.00104	.002	-.0103	-.0046
			FD 48h	-.00433*	.00104	.014	-.0072	-.0014

*. The mean difference is significant at the 0.05 level.

D.5 Statistical analysis of LAB and yeast counts of bread dough (BD) samples before proofing (BP) and after proofing (AP) of GF sweet potato sourdough breads

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
LAB_BD_BP	Control	2	7.8886	.03570	.02525	7.5678	8.2093	7.86	7.91
	RS	2	7.2282	.16156	.11424	5.7766	8.6797	7.11	7.34
	RS/RK	2	7.5425	.05277	.03732	7.0683	8.0166	7.51	7.58
	RS/ISD	2	8.0489	.02194	.01552	7.8518	8.2461	8.03	8.06
	Control/RP	2	7.4494	.09779	.06915	6.5707	8.3280	7.38	7.52
	Total	10	7.6315	.32118	.10157	7.4017	7.8613	7.11	8.06
LAB_BD_AP	Control	2	8.4537	.02484	.01756	8.2305	8.6769	8.44	8.47
	RS	2	8.4065	.01204	.00852	8.2982	8.5147	8.40	8.41
	RS/RK	2	8.3816	.04714	.03333	7.9581	8.8052	8.35	8.41
	RS/ISD	2	8.5888	.00317	.00224	8.5604	8.6173	8.59	8.59
	Control/RP	2	8.3482	.01377	.00974	8.2244	8.4719	8.34	8.36
	Total	10	8.4358	.09043	.02860	8.3711	8.5005	8.34	8.59
Yeast_BD_BP	Control	2	7.9590	.00675	.00477	7.8984	8.0197	7.95	7.96
	RS	2	7.7966	.06853	.04846	7.1810	8.4123	7.75	7.85
	RS/RK	2	7.7662	.12022	.08501	6.6861	8.8464	7.68	7.85
	RS/ISD	2	7.9151	.04849	.03429	7.4794	8.3508	7.88	7.95
	Control/RP	2	7.9051	.03437	.02430	7.5963	8.2139	7.88	7.93
	Total	10	7.8684	.09272	.02932	7.8021	7.9348	7.68	7.96
Yeast_BD_AP	Control	2	8.2173	.01862	.01316	8.0500	8.3846	8.20	8.23
	RS	2	8.2068	.00381	.00270	8.1725	8.2411	8.20	8.21
	RS/RK	2	8.2095	.00379	.00268	8.1754	8.2436	8.21	8.21
	RS/ISD	2	8.3220	.01755	.01241	8.1643	8.4797	8.31	8.33
	Control/RP	2	8.2316	.08262	.05842	7.4893	8.9740	8.17	8.29
	Total	10	8.2375	.05389	.01704	8.1989	8.2760	8.17	8.33

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
LAB_BD_BP	Between Groups	.888	4	.222	27.614	.001
	Within Groups	.040	5	.008		
	Total	.928	9			
LAB_BD_AP	Between Groups	.070	4	.018	27.642	.001
	Within Groups	.003	5	.001		
	Total	.074	9			
Yeast_BD_BP	Between Groups	.055	4	.014	3.006	.129
	Within Groups	.023	5	.005		
	Total	.077	9			
Yeast_BD_AP	Between Groups	.019	4	.005	3.101	.123
	Within Groups	.008	5	.002		
	Total	.026	9			

Multiple Comparisons

Dependent Variable		(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
							Lower Bound	Upper Bound	
LAB_BD_BP	Tukey HSD	Control	RS	.66039 [*]	.08967	.004	.3007	1.0201	
			RS/RK	.34610	.08967	.058	-.0136	.7058	
			RS/ISD	-.16037	.08967	.466	-.5201	.1994	
			Control/RP	.43921 [*]	.08967	.023	.0795	.7989	
		RS	Control	-.66039 [*]	.08967	.004	-1.0201	-.3007	
			RS/RK	-.31428	.08967	.081	-.6740	.0454	
			RS/ISD	-.82076 [*]	.08967	.001	-1.1805	-.4610	
			Control/RP	-.22118	.08967	.236	-.5809	.1385	
		RS/RK	Control	-.34610	.08967	.058	-.7058	.0136	
			RS	.31428	.08967	.081	-.0454	.6740	
			RS/ISD	-.50647 [*]	.08967	.013	-.8662	-.1467	
			Control/RP	.09310	.08967	.829	-.2666	.4528	
		RS/ISD	Control	.16037	.08967	.466	-.1994	.5201	
			RS	.82076 [*]	.08967	.001	.4610	1.1805	
			RS/RK	.50647 [*]	.08967	.013	.1467	.8662	
			Control/RP	.59958 [*]	.08967	.006	.2399	.9593	
		Control/RP	Control	-.43921 [*]	.08967	.023	-.7989	-.0795	
			RS	.22118	.08967	.236	-.1385	.5809	
			RS/RK	-.09310	.08967	.829	-.4528	.2666	
			RS/ISD	-.59958 [*]	.08967	.006	-.9593	-.2399	
	LSD	Control	RS	.66039 [*]	.08967	.001	.4299	.8909	
			RS/RK	.34610 [*]	.08967	.012	.1156	.5766	
			RS/ISD	-.16037	.08967	.134	-.3909	.0701	
			Control/RP	.43921 [*]	.08967	.004	.2087	.6697	
		RS	Control	-.66039 [*]	.08967	.001	-.8909	-.4299	
			RS/RK	-.31428 [*]	.08967	.017	-.5448	-.0838	
			RS/ISD	-.82076 [*]	.08967	.000	-1.0513	-.5902	
			Control/RP	-.22118	.08967	.057	-.4517	.0093	
		RS/RK	Control	-.34610 [*]	.08967	.012	-.5766	-.1156	
			RS	.31428 [*]	.08967	.017	.0838	.5448	
			RS/ISD	-.50647 [*]	.08967	.002	-.7370	-.2760	
			Control/RP	.09310	.08967	.347	-.1374	.3236	
		RS/ISD	Control	.16037	.08967	.134	-.0701	.3909	
			RS	.82076 [*]	.08967	.000	.5902	1.0513	
			RS/RK	.50647 [*]	.08967	.002	.2760	.7370	
			Control/RP	.59958 [*]	.08967	.001	.3691	.8301	
		Control/RP	Control	-.43921 [*]	.08967	.004	-.6697	-.2087	
			RS	.22118	.08967	.057	-.0093	.4517	
			RS/RK	-.09310	.08967	.347	-.3236	.1374	
			RS/ISD	-.59958 [*]	.08967	.001	-.8301	-.3691	
	LAB_BD_AP	Tukey HSD	Control	RS	.04727	.02524	.430	-.0540	.1485
				RS/RK	.07209	.02524	.157	-.0291	.1733
				RS/ISD	-.13510 [*]	.02524	.016	-.2363	-.0339
				Control/RP	.10553 [*]	.02524	.043	.0043	.2068
RS			Control	-.04727	.02524	.430	-.1485	.0540	
			RS/RK	.02482	.02524	.853	-.0764	.1261	
			RS/ISD	-.18237 [*]	.02524	.004	-.2836	-.0811	
			Control/RP	.05826	.02524	.278	-.0430	.1595	
RS/RK			Control	-.07209	.02524	.157	-.1733	.0291	
			RS	-.02482	.02524	.853	-.1261	.0764	
			RS/ISD	-.20719 [*]	.02524	.002	-.3084	-.1060	
			Control/RP	.03344	.02524	.691	-.0678	.1347	
RS/ISD			Control	.13510 [*]	.02524	.016	.0339	.2363	
			RS	.18237 [*]	.02524	.004	.0811	.2836	

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval					
						Lower Bound	Upper Bound				
Yeast_BD_BP	LSD	RS/RK	.20719 [*]	.02524	.002	.1060	.3084				
			Control/RP	.24063 [*]	.02524	.001	.1394	.3419			
		Control/RP	Control	-.10553 [*]	.02524	.043	-.2068	-.0043			
			RS	-.05826	.02524	.278	-.1595	.0430			
		RS/RK	RS/RK	-.03344	.02524	.691	-.1347	.0678			
			RS/ISD	-.24063 [*]	.02524	.001	-.3419	-.1394			
		Control	RS	.04727	.02524	.120	-.0176	.1121			
			RS/RK	.07209 [*]	.02524	.036	.0072	.1370			
			RS/ISD	-.13510 [*]	.02524	.003	-.2000	-.0702			
			Control/RP	.10553 [*]	.02524	.009	.0407	.1704			
		RS	Control	-.04727	.02524	.120	-.1121	.0176			
			RS/RK	.02482	.02524	.371	-.0401	.0897			
			RS/ISD	-.18237 [*]	.02524	.001	-.2472	-.1175			
			Control/RP	.05826	.02524	.069	-.0066	.1231			
		RS/RK	Control	-.07209 [*]	.02524	.036	-.1370	-.0072			
			RS	-.02482	.02524	.371	-.0897	.0401			
			RS/ISD	-.20719 [*]	.02524	.000	-.2721	-.1423			
			Control/RP	.03344	.02524	.242	-.0314	.0983			
		RS/ISD	Control	.13510 [*]	.02524	.003	.0702	.2000			
			RS	.18237 [*]	.02524	.001	.1175	.2472			
			RS/RK	.20719 [*]	.02524	.000	.1423	.2721			
			Control/RP	.24063 [*]	.02524	.000	.1758	.3055			
		Control/RP	Control	-.10553 [*]	.02524	.009	-.1704	-.0407			
			RS	-.05826	.02524	.069	-.1231	.0066			
			RS/RK	-.03344	.02524	.242	-.0983	.0314			
			RS/ISD	-.24063 [*]	.02524	.000	-.3055	-.1758			
		Yeast_BD_BP	Tukey HSD	Control	RS	.16237	.06742	.250	-.1081	.4328	
					RS/RK	.19277	.06742	.157	-.0777	.4632	
					RS/ISD	.04391	.06742	.959	-.2265	.3144	
					Control/RP	.05390	.06742	.920	-.2166	.3244	
				RS	Control	-.16237	.06742	.250	-.4328	.1081	
					RS/RK	.03039	.06742	.989	-.2401	.3008	
					RS/ISD	-.11846	.06742	.480	-.3889	.1520	
					Control/RP	-.10847	.06742	.549	-.3789	.1620	
				RS/RK	Control	-.19277	.06742	.157	-.4632	.0777	
					RS	-.03039	.06742	.989	-.3008	.2401	
					RS/ISD	-.14885	.06742	.308	-.4193	.1216	
					Control/RP	-.13887	.06742	.358	-.4093	.1316	
				RS/ISD	Control	-.04391	.06742	.959	-.3144	.2265	
					RS	.11846	.06742	.480	-.1520	.3889	
					RS/RK	.14885	.06742	.308	-.1216	.4193	
					Control/RP	.00999	.06742	1.000	-.2605	.2604	
				Control/RP	Control	-.05390	.06742	.920	-.3244	.2166	
					RS	.10847	.06742	.549	-.1620	.3789	
					RS/RK	.13887	.06742	.358	-.1316	.4093	
					RS/ISD	-.00999	.06742	1.000	-.2604	.2605	
				LSD	Control	RS	.16237	.06742	.061	-.0109	.3357
						RS/RK	.19277 [*]	.06742	.035	.0195	.3661
RS/ISD	.04391					.06742	.544	-.1294	.2172		
Control/RP	.05390					.06742	.460	-.1194	.2272		
RS	Control				-.16237	.06742	.061	-.3357	.0109		
	RS/RK				.03039	.06742	.671	-.1429	.2037		
	RS/ISD				-.11846	.06742	.139	-.2918	.0548		
	Control/RP				-.10847	.06742	.169	-.2818	.0648		
RS/RK	Control				-.19277 [*]	.06742	.035	-.3661	-.0195		
	RS				-.03039	.06742	.671	-.2037	.1429		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
		RS/ISD	-.14885	.06742	.078	-.3222	.0246		
		Control/RP	-.13887	.06742	.094	-.3122	.0344		
	RS/ISD	Control	-.04391	.06742	.544	-.2172	.1294		
		RS	.11846	.06742	.139	-.0548	.2918		
		RS/RK	.14885	.06742	.078	-.0246	.3222		
		Control/RP	.00999	.06742	.888	-.1633	.1833		
	Control/RP	Control	-.05390	.06742	.460	-.2272	.1194		
		RS	.10847	.06742	.169	-.0648	.2818		
		RS/RK	.13887	.06742	.094	-.0344	.3122		
		RS/ISD	-.00999	.06742	.888	-.1833	.1833		
	Yeast_BD_AP	Tukey HSD	Control	RS	.01047	.03876	.998	-.1460	.1659
				RS/RK	.00778	.03876	1.000	-.1477	.1633
				RS/ISD	-.10476	.03876	.184	-.2602	.0507
				Control/RP	-.01433	.03876	.995	-.1698	.1411
RS			Control	-.01047	.03876	.998	-.1659	.1460	
			RS/RK	-.00269	.03876	1.000	-.1582	.1528	
			RS/ISD	-.11522	.03876	.139	-.2707	.0402	
			Control/RP	-.02479	.03876	.961	-.1803	.1307	
RS/RK			Control	-.00778	.03876	1.000	-.1633	.1477	
			RS	.00269	.03876	1.000	-.1528	.1582	
			RS/ISD	-.11254	.03876	.150	-.2680	.0429	
			Control/RP	-.02210	.03876	.974	-.1776	.1334	
RS/ISD			Control	.10476	.03876	.184	-.0507	.2602	
			RS	.11522	.03876	.139	-.0402	.2707	
			RS/RK	.11254	.03876	.150	-.0429	.2680	
			Control/RP	.09043	.03876	.271	-.0650	.2469	
Control/RP			Control	.01433	.03876	.995	-.1411	.1698	
			RS	.02479	.03876	.961	-.1307	.1803	
		RS/RK	.02210	.03876	.974	-.1334	.1776		
		RS/ISD	-.09043	.03876	.271	-.2469	.0650		
LSD		Control	RS	.01047	.03876	.798	-.0892	.1101	
			RS/RK	.00778	.03876	.849	-.0918	.1074	
			RS/ISD	-.10476 [*]	.03876	.043	-.2044	-.0051	
			Control/RP	-.01433	.03876	.727	-.1140	.0853	
		RS	Control	-.01047	.03876	.798	-.1101	.0892	
			RS/RK	-.00269	.03876	.947	-.1023	.0969	
			RS/ISD	-.11522 [†]	.03876	.031	-.2149	-.0156	
			Control/RP	-.02479	.03876	.551	-.1244	.0748	
		RS/RK	Control	-.00778	.03876	.849	-.1074	.0918	
			RS	.00269	.03876	.947	-.0969	.1023	
			RS/ISD	-.11254 [*]	.03876	.034	-.2122	-.0129	
			Control/RP	-.02210	.03876	.593	-.1217	.0775	
		RS/ISD	Control	.10476 [*]	.03876	.043	.0051	.2044	
			RS	.11522 [†]	.03876	.031	.0156	.2149	
RS/RK			.11254 [†]	.03876	.034	.0129	.2122		
Control/RP			.09043	.03876	.067	-.0092	.1901		
Control/RP		Control	.01433	.03876	.727	-.0853	.1140		
		RS	.02479	.03876	.551	-.0748	.1244		
		RS/RK	.02210	.03876	.593	-.0775	.1217		
		RS/ISD	-.09043	.03876	.067	-.1901	.0092		

LAB_BD_BP

		N	Subset for alpha = 0.05		
Breaddough			1	2	3
Tukey HSD ^a	RS	2	7.2282		
	Control/RP	2	7.4494		
	RS/RK	2	7.5425	7.5425	
	Control	2		7.8886	7.8886
	RS/ISD	2			8.0489
	Sig.			.081	.058

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

LAB_BD_AP

		N	Subset for alpha = 0.05		
Breaddough			1	2	3
Tukey HSD ^a	Control/RP	2	8.3482		
	RS/RK	2	8.3816	8.3816	
	RS	2	8.4065	8.4065	
	Control	2		8.4537	
	RS/ISD	2			8.5888
	Sig.			.278	.157

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Yeast_BD_BP

		N	Subset for alpha = 0.05
Breaddough			1
Tukey HSD ^a	RS/RK	2	7.7662
	RS	2	7.7966
	Control/RP	2	7.9051
	RS/ISD	2	7.9151
	Control	2	7.9590
	Sig.		

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Yeast_BD_AP

		N	Subset for alpha = 0.05
Breaddough			1
Tukey HSD ^a	RS	2	8.2068
	RS/RK	2	8.2095
	Control	2	8.2173
	Control/RP	2	8.2316
	RS/ISD	2	8.3220
	Sig.		

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

D.6 Statistical analysis of pH and TTA of bread dough (BD) samples before proofing (BP) and after proofing (AP), and bread samples of GF sweet potato sourdough breads

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH_BD_BP	Control	3	4.5367	.02082	.01202	4.4850	4.5884	4.52	4.56
	RS	3	4.4667	.01528	.00882	4.4287	4.5046	4.45	4.48
	RS/RK	3	4.3900	.01000	.00577	4.3652	4.4148	4.38	4.40
	RS/ISD	3	4.2433	.00577	.00333	4.2290	4.2577	4.24	4.25
	Control/RP	3	4.5567	.00577	.00333	4.5423	4.5710	4.55	4.56
	Total	15	4.4387	.11837	.03056	4.3731	4.5042	4.24	4.56
pH_BD_AP	Control	3	4.4367	.01528	.00882	4.3987	4.4746	4.42	4.45
	RS	3	4.3267	.01155	.00667	4.2980	4.3554	4.32	4.34
	RS/RK	3	4.1967	.00577	.00333	4.1823	4.2110	4.19	4.20
	RS/ISD	3	4.1900	.01000	.00577	4.1652	4.2148	4.18	4.20
	Control/RP	3	4.5233	.01528	.00882	4.4854	4.5613	4.51	4.54
	Total	15	4.3347	.13617	.03516	4.2593	4.4101	4.18	4.54
TTA_BD_BP	Control	3	4.1000	.05000	.02887	3.9758	4.2242	4.05	4.15
	RS	3	4.3667	.02887	.01667	4.2950	4.4384	4.35	4.40
	RS/RK	3	4.2333	.05774	.03333	4.0899	4.3768	4.20	4.30
	RS/ISD	3	4.9600	.05000	.02887	4.8358	5.0842	4.91	5.01
	Control/RP	3	4.0833	.02887	.01667	4.0116	4.1550	4.05	4.10
	Total	15	4.3487	.33581	.08671	4.1627	4.5346	4.05	5.01
TTA_BD_AP	Control	3	4.2833	.02887	.01667	4.2116	4.3550	4.25	4.30
	RS	3	4.5767	.02887	.01667	4.5050	4.6484	4.56	4.61
	RS/RK	3	4.4667	.02887	.01667	4.3950	4.5384	4.45	4.50
	RS/ISD	3	5.3600	.05000	.02887	5.2358	5.4842	5.31	5.41
	Control/RP	3	4.3000	.05000	.02887	4.1758	4.4242	4.25	4.35
	Total	15	4.5973	.41175	.10631	4.3693	4.8254	4.25	5.41

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH_BD_BP	Between Groups	.195	4	.049	291.760	.000
	Within Groups	.002	10	.000		
	Total	.196	14			
pH_BD_AP	Between Groups	.258	4	.065	439.955	.000
	Within Groups	.001	10	.000		
	Total	.260	14			
TTA_BD_BP	Between Groups	1.559	4	.390	194.847	.000
	Within Groups	.020	10	.002		
	Total	1.579	14			
TTA_BD_AP	Between Groups	2.358	4	.590	393.082	.000
	Within Groups	.015	10	.001		
	Total	2.373	14			

Multiple Comparisons

Dependent Variable		(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval					
							Lower Bound	Upper Bound				
pH_BD_BP	Tukey HSD	Control	RS	.07000 [*]	.01054	.000	.0353	.1047				
			RS/RK	.14667 [*]	.01054	.000	.1120	.1814				
			RS/ISD	.29333 [*]	.01054	.000	.2586	.3280				
			Control/RP	-.02000	.01054	.377	-.0547	.0147				
		RS	Control	-.07000 [*]	.01054	.000	-.1047	-.0353				
			RS/RK	.07667 [*]	.01054	.000	.0420	.1114				
			RS/ISD	.22333 [*]	.01054	.000	.1886	.2580				
			Control/RP	-.09000 [*]	.01054	.000	-.1247	-.0553				
		RS/RK	Control	-.14667 [*]	.01054	.000	-.1814	-.1120				
			RS	-.07667 [*]	.01054	.000	-.1114	-.0420				
			RS/ISD	.14667 [*]	.01054	.000	.1120	.1814				
			Control/RP	-.16667 [*]	.01054	.000	-.2014	-.1320				
		RS/ISD	Control	-.29333 [*]	.01054	.000	-.3280	-.2586				
			RS	-.22333 [*]	.01054	.000	-.2580	-.1886				
			RS/RK	-.14667 [*]	.01054	.000	-.1814	-.1120				
			Control/RP	-.31333 [*]	.01054	.000	-.3480	-.2786				
		Control/RP	Control	.02000	.01054	.377	-.0147	.0547				
			RS	.09000 [*]	.01054	.000	.0553	.1247				
			RS/RK	.16667 [*]	.01054	.000	.1320	.2014				
			RS/ISD	.31333 [*]	.01054	.000	.2786	.3480				
		LSD		Control	RS	.07000 [*]	.01054	.000	.0465	.0935		
					RS/RK	.14667 [*]	.01054	.000	.1232	.1702		
					RS/ISD	.29333 [*]	.01054	.000	.2698	.3168		
					Control/RP	-.02000	.01054	.087	-.0435	.0035		
				RS	Control	-.07000 [*]	.01054	.000	-.0935	-.0465		
					RS/RK	.07667 [*]	.01054	.000	.0532	.1002		
					RS/ISD	.22333 [*]	.01054	.000	.1998	.2468		
					Control/RP	-.09000 [*]	.01054	.000	-.1135	-.0665		
				RS/RK	Control	-.14667 [*]	.01054	.000	-.1702	-.1232		
					RS	-.07667 [*]	.01054	.000	-.1002	-.0532		
					RS/ISD	.14667 [*]	.01054	.000	.1232	.1702		
					Control/RP	-.16667 [*]	.01054	.000	-.1902	-.1432		
				RS/ISD	Control	-.29333 [*]	.01054	.000	-.3168	-.2698		
					RS	-.22333 [*]	.01054	.000	-.2468	-.1998		
					RS/RK	-.14667 [*]	.01054	.000	-.1702	-.1232		
					Control/RP	-.31333 [*]	.01054	.000	-.3368	-.2898		
				Control/RP	Control	.02000	.01054	.087	-.0035	.0435		
					RS	.09000 [*]	.01054	.000	.0665	.1135		
					RS/RK	.16667 [*]	.01054	.000	.1432	.1902		
					RS/ISD	.31333 [*]	.01054	.000	.2898	.3368		
				pH_BD_AP	Tukey HSD	Control	RS	.11000 [*]	.00989	.000	.0775	.1425
							RS/RK	.24000 [*]	.00989	.000	.2075	.2725
							RS/ISD	.24667 [*]	.00989	.000	.2141	.2792
							Control/RP	-.08667 [*]	.00989	.000	-.1192	-.0541
						RS	Control	-.11000 [*]	.00989	.000	-.1425	-.0775
							RS/RK	.13000 [*]	.00989	.000	.0975	.1625
							RS/ISD	.13667 [*]	.00989	.000	.1041	.1692
							Control/RP	-.19667 [*]	.00989	.000	-.2292	-.1641
RS/RK	Control					-.24000 [*]	.00989	.000	-.2725	-.2075		
	RS					-.13000 [*]	.00989	.000	-.1625	-.0975		
	RS/ISD					.00667	.00989	.958	-.0259	.0392		
	Control/RP					-.32667 [*]	.00989	.000	-.3592	-.2941		
RS/ISD	Control					-.24667 [*]	.00989	.000	-.2792	-.2141		
	RS					-.13667 [*]	.00989	.000	-.1692	-.1041		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval					
						Lower Bound	Upper Bound				
TTA_BD_BP	LSD	Control/RP	RS/RK	-.00667	.00989	.958	-.0392	.0259			
			Control/RP	-.33333	.00989	.000	-.3659	-.3008			
		Control	Control	.08667	.00989	.000	.0541	.1192			
			RS	.19667	.00989	.000	.1641	.2292			
		RS/RK	RS/RK	.32667	.00989	.000	.2941	.3592			
			RS/ISD	.33333	.00989	.000	.3008	.3659			
		RS	Control	RS	.11000	.00989	.000	.0880	.1320		
				RS/RK	.24000	.00989	.000	.2180	.2620		
				RS/ISD	.24667	.00989	.000	.2246	.2687		
				Control/RP	-.08667	.00989	.000	-.1087	-.0646		
		RS	RS	Control	-.11000	.00989	.000	-.1320	-.0880		
				RS/RK	.13000	.00989	.000	.1080	.1520		
				RS/ISD	.13667	.00989	.000	.1146	.1587		
				Control/RP	-.19667	.00989	.000	-.2187	-.1746		
		RS/RK	Control	Control	-.24000	.00989	.000	-.2620	-.2180		
				RS	-.13000	.00989	.000	-.1520	-.1080		
				RS/ISD	.00667	.00989	.515	-.0154	.0287		
				Control/RP	-.32667	.00989	.000	-.3487	-.3046		
		RS/ISD	Control	Control	-.24667	.00989	.000	-.2687	-.2246		
				RS	-.13667	.00989	.000	-.1587	-.1146		
				RS/RK	-.00667	.00989	.515	-.0287	.0154		
				Control/RP	-.33333	.00989	.000	-.3554	-.3113		
		Control/RP	Control	Control	.08667	.00989	.000	.0646	.1087		
				RS	.19667	.00989	.000	.1746	.2187		
				RS/RK	.32667	.00989	.000	.3046	.3487		
				RS/ISD	.33333	.00989	.000	.3113	.3554		
		TTA_BD_BP	Tukey HSD	Control	RS	-.26667	.03651	.000	-.3868	-.1465	
					RS/RK	-.13333	.03651	.029	-.2535	-.0132	
					RS/ISD	-.86000	.03651	.000	-.9802	-.7398	
					Control/RP	.01667	.03651	.990	-.1035	.1368	
				RS	Control	.26667	.03651	.000	.1465	.3868	
					RS/RK	.13333	.03651	.029	.0132	.2535	
					RS/ISD	-.59333	.03651	.000	-.7135	-.4732	
					Control/RP	.28333	.03651	.000	.1632	.4035	
				RS/RK	Control	.13333	.03651	.029	.0132	.2535	
					RS	-.13333	.03651	.029	-.2535	-.0132	
					RS/ISD	-.72667	.03651	.000	-.8468	-.6065	
					Control/RP	.15000	.03651	.014	.0298	.2702	
				RS/ISD	Control	.86000	.03651	.000	.7398	.9802	
					RS	.59333	.03651	.000	.4732	.7135	
					RS/RK	.72667	.03651	.000	.6065	.8468	
					Control/RP	.87667	.03651	.000	.7565	.9968	
				Control/RP	Control	-.01667	.03651	.990	-.1368	.1035	
					RS	-.28333	.03651	.000	-.4035	-.1632	
					RS/RK	-.15000	.03651	.014	-.2702	-.0298	
					RS/ISD	-.87667	.03651	.000	-.9968	-.7565	
				LSD	Control	RS	-.26667	.03651	.000	-.3480	-.1853
						RS/RK	-.13333	.03651	.004	-.2147	-.0520
RS/ISD	-.86000					.03651	.000	-.9414	-.7786		
Control/RP	.01667					.03651	.658	-.0647	.0980		
RS	Control				.26667	.03651	.000	.1853	.3480		
	RS/RK				.13333	.03651	.004	.0520	.2147		
	RS/ISD				-.59333	.03651	.000	-.6747	-.5120		
	Control/RP				.28333	.03651	.000	.2020	.3647		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound		
	RS/RK	Control	.13333 [*]	.03651	.004	.0520	.2147		
		RS	-.13333 [*]	.03651	.004	-.2147	-.0520		
		RS/ISD	-.72667 [*]	.03651	.000	-.8080	-.6453		
		Control/RP	.15000 [*]	.03651	.002	.0686	.2314		
	RS/ISD	Control	.86000 [*]	.03651	.000	.7786	.9414		
		RS	.59333 [*]	.03651	.000	.5120	.6747		
		RS/RK	.72667 [*]	.03651	.000	.6453	.8080		
		Control/RP	.87667 [*]	.03651	.000	.7953	.9580		
	Control/RP	Control	-.01667	.03651	.658	-.0980	.0647		
		RS	-.28333 [*]	.03651	.000	-.3647	-.2020		
		RS/RK	-.15000 [*]	.03651	.002	-.2314	-.0686		
		RS/ISD	-.87667 [*]	.03651	.000	-.9580	-.7953		
TTA_BD_AP	Tukey HSD	Control	RS	-.29333 [*]	.03162	.000	-.3974	-.1893	
			RS/RK	-.18333 [*]	.03162	.001	-.2874	-.0793	
			RS/ISD	-1.07667 [*]	.03162	.000	-1.1807	-.9726	
			Control/RP	-.01667	.03162	.982	-.1207	.0874	
		RS	Control	.29333 [*]	.03162	.000	.1893	.3974	
			RS/RK	.11000 [*]	.03162	.037	.0059	.2141	
			RS/ISD	-.78333 [*]	.03162	.000	-.8874	-.6793	
			Control/RP	.27667 [*]	.03162	.000	.1726	.3807	
		RS/RK	Control	.18333 [*]	.03162	.001	.0793	.2874	
			RS	-.11000 [*]	.03162	.037	-.2141	-.0059	
			RS/ISD	-.89333 [*]	.03162	.000	-.9974	-.7893	
			Control/RP	.16667 [*]	.03162	.003	.0626	.2707	
	RS/ISD	Control	1.07667 [*]	.03162	.000	.9726	1.1807		
		RS	.78333 [*]	.03162	.000	.6793	.8874		
		RS/RK	.89333 [*]	.03162	.000	.7893	.9974		
		Control/RP	1.06000 [*]	.03162	.000	.9559	1.1641		
	Control/RP	Control	.01667	.03162	.982	-.0874	.1207		
		RS	-.27667 [*]	.03162	.000	-.3807	-.1726		
		RS/RK	-.16667 [*]	.03162	.003	-.2707	-.0626		
		RS/ISD	-1.06000 [*]	.03162	.000	-1.1641	-.9559		
	LSD	Control	RS	RS	-.29333 [*]	.03162	.000	-.3638	-.2229
				RS/RK	-.18333 [*]	.03162	.000	-.2538	-.1129
				RS/ISD	-1.07667 [*]	.03162	.000	-1.1471	-1.0062
				Control/RP	-.01667	.03162	.610	-.0871	.0538
			RS	Control	.29333 [*]	.03162	.000	.2229	.3638
				RS/RK	.11000 [*]	.03162	.006	.0395	.1805
				RS/ISD	-.78333 [*]	.03162	.000	-.8538	-.7129
				Control/RP	.27667 [*]	.03162	.000	.2062	.3471
			RS/RK	Control	.18333 [*]	.03162	.000	.1129	.2538
				RS	-.11000 [*]	.03162	.006	-.1805	-.0395
				RS/ISD	-.89333 [*]	.03162	.000	-.9638	-.8229
				Control/RP	.16667 [*]	.03162	.000	.0962	.2371
		RS/ISD	Control	1.07667 [*]	.03162	.000	1.0062	1.1471	
			RS	.78333 [*]	.03162	.000	.7129	.8538	
			RS/RK	.89333 [*]	.03162	.000	.8229	.9638	
			Control/RP	1.06000 [*]	.03162	.000	.9895	1.1305	
Control/RP		Control	.01667	.03162	.610	-.0538	.0871		
		RS	-.27667 [*]	.03162	.000	-.3471	-.2062		
		RS/RK	-.16667 [*]	.03162	.000	-.2371	-.0962		
		RS/ISD	-1.06000 [*]	.03162	.000	-1.1305	-.9895		

*. The mean difference is significant at the 0.05 level.

pH_BD_BP

		N	Subset for alpha = 0.05			
Breaddough			1	2	3	4
Tukey HSD ^a	RS/ISD	3	4.2433			
	RS/RK	3		4.3900		
	RS	3			4.4667	
	Control	3				4.5367
	Control/RP	3				4.5667
Sig.			1.000	1.000	1.000	.377

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

pH_BD_AP

		N	Subset for alpha = 0.05			
Breaddough			1	2	3	4
Tukey HSD ^a	RS/ISD	3	4.1900			
	RS/RK	3	4.1967			
	RS	3		4.3267		
	Control	3			4.4367	
	Control/RP	3				4.5233
Sig.			.958	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

TTA_BD_BP

		N	Subset for alpha = 0.05			
Breaddough			1	2	3	4
Tukey HSD ^a	Control/RP	3	4.0833			
	Control	3	4.1000			
	RS/RK	3		4.2333		
	RS	3			4.3667	
	RS/ISD	3				4.9600
Sig.			.990	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

TTA_BD_AP

		N	Subset for alpha = 0.05			
Breaddough			1	2	3	4
Tukey HSD ^a	Control	3	4.2833			
	Control/RP	3	4.3000			
	RS/RK	3		4.4667		
	RS	3			4.5767	
	RS/ISD	3				5.3600
Sig.			.982	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
pH_Bread	Control	9	4.5778	.06220	.02073	4.5300	4.6256	4.50	4.66
	RS	9	4.5122	.01394	.00465	4.5015	4.5229	4.49	4.53
	RS/RK	9	4.4178	.04206	.01402	4.3854	4.4501	4.35	4.47
	RS/ISD	9	4.2822	.05094	.01698	4.2431	4.3214	4.21	4.33
	Control/RP	9	4.6056	.02877	.00959	4.5834	4.6277	4.57	4.65
	Total	45	4.4791	.12597	.01878	4.4413	4.5170	4.21	4.66
TTA_Bread	Control	9	3.5167	.05000	.01667	3.4782	3.5551	3.46	3.60
	RS	9	4.2944	.06346	.02115	4.2457	4.3432	4.20	4.40
	RS/RK	9	4.2222	.10929	.03643	4.1382	4.3062	4.10	4.40
	RS/ISD	9	4.8822	.05652	.01884	4.8388	4.9257	4.76	4.96
	Control/RP	9	3.4389	.07817	.02606	3.3788	3.4990	3.30	3.55
	Total	45	4.0709	.54693	.08153	3.9066	4.2352	3.30	4.96

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
pH_Bread	Between Groups	.624	4	.156	84.290	.000
	Within Groups	.074	40	.002		
	Total	.698	44			
TTA_Bread	Between Groups	12.940	4	3.235	582.279	.000
	Within Groups	.222	40	.006		
	Total	13.162	44			

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval						
						Lower Bound	Upper Bound					
pH_Bread	Tukey HSD	Control	RS	.06556 [*]	.02028	.020	.0076	.1235				
			RS/RK	.16000 [*]	.02028	.000	.1021	.2179				
			RS/ISD	.29556 [*]	.02028	.000	.2376	.3535				
			Control/RP	-.02778	.02028	.650	-.0857	.0301				
		RS	Control	-.06556 [*]	.02028	.020	-.1235	-.0076				
			RS/RK	.09444 [*]	.02028	.000	.0365	.1524				
			RS/ISD	.23000 [*]	.02028	.000	.1721	.2879				
			Control/RP	-.09333 [*]	.02028	.000	-.1513	-.0354				
		RS/RK	Control	-.16000 [*]	.02028	.000	-.2179	-.1021				
			RS	-.09444 [*]	.02028	.000	-.1524	-.0365				
			RS/ISD	.13556 [*]	.02028	.000	.0776	.1935				
			Control/RP	-.18778 [*]	.02028	.000	-.2457	-.1299				
		RS/ISD	Control	-.29556 [*]	.02028	.000	-.3535	-.2376				
			RS	-.23000 [*]	.02028	.000	-.2879	-.1721				
			RS/RK	-.13556 [*]	.02028	.000	-.1935	-.0776				
			Control/RP	-.32333 [*]	.02028	.000	-.3813	-.2654				
		Control/RP	Control	.02778	.02028	.650	-.0301	.0857				
			RS	.09333 [*]	.02028	.000	.0354	.1513				
			RS/RK	.18778 [*]	.02028	.000	.1299	.2457				
			RS/ISD	.32333 [*]	.02028	.000	.2654	.3813				
		LSD	LSD	Control	RS	.06556 [*]	.02028	.002	.0246	.1065		
					RS/RK	.16000 [*]	.02028	.000	.1190	.2010		
					RS/ISD	.29556 [*]	.02028	.000	.2546	.3365		
					Control/RP	-.02778	.02028	.178	-.0688	.0132		
				RS	Control	-.06556 [*]	.02028	.002	-.1065	-.0246		
					RS/RK	.09444 [*]	.02028	.000	.0535	.1354		
					RS/ISD	.23000 [*]	.02028	.000	.1890	.2710		
					Control/RP	-.09333 [*]	.02028	.000	-.1343	-.0523		
				RS/RK	Control	-.16000 [*]	.02028	.000	-.2010	-.1190		
					RS	-.09444 [*]	.02028	.000	-.1354	-.0535		
					RS/ISD	.13556 [*]	.02028	.000	.0946	.1765		
					Control/RP	-.18778 [*]	.02028	.000	-.2288	-.1468		
				RS/ISD	Control	-.29556 [*]	.02028	.000	-.3365	-.2546		
					RS	-.23000 [*]	.02028	.000	-.2710	-.1890		
					RS/RK	-.13556 [*]	.02028	.000	-.1765	-.0946		
					Control/RP	-.32333 [*]	.02028	.000	-.3643	-.2823		
				Control/RP	Control	.02778	.02028	.178	-.0132	.0688		
					RS	.09333 [*]	.02028	.000	.0523	.1343		
					RS/RK	.18778 [*]	.02028	.000	.1468	.2288		
					RS/ISD	.32333 [*]	.02028	.000	.2823	.3643		
				TTA_Bread	Tukey HSD	Control	RS	-.77778 [*]	.03514	.000	-.8781	-.6774
							RS/RK	-.70556 [*]	.03514	.000	-.8059	-.6052
							RS/ISD	-1.36556 [*]	.03514	.000	-1.4659	-1.2652
							Control/RP	.07778	.03514	.196	-.0226	.1781
						RS	Control	.77778 [*]	.03514	.000	.6774	.8781
							RS/RK	.07222	.03514	.259	-.0281	.1726
							RS/ISD	-.58778 [*]	.03514	.000	-.6881	-.4874
							Control/RP	.85556 [*]	.03514	.000	.7552	.9559
RS/RK	Control					.70556 [*]	.03514	.000	.6052	.8059		
	RS					-.07222	.03514	.259	-.1726	.0281		
	RS/ISD					-.66000 [*]	.03514	.000	-.7604	-.5596		
	Control/RP					.78333 [*]	.03514	.000	.6830	.8837		
RS/ISD	Control					1.36556 [*]	.03514	.000	1.2652	1.4659		
	RS					.58778 [*]	.03514	.000	.4874	.6881		

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	Control/RP	RS/RK	.66000 [*]	.03514	.000	.5596	.7604
		Control/RP	1.44333 [*]	.03514	.000	1.3430	1.5437
	Control/RP	Control	-.07778	.03514	.196	-.1781	.0226
		RS	-.85556 [*]	.03514	.000	-.9559	-.7552
	Control/RP	RS/RK	-.78333 [*]	.03514	.000	-.8837	-.6830
		RS/ISD	-1.44333 [*]	.03514	.000	-1.5437	-1.3430
	Control	RS	-.77778 [*]	.03514	.000	-.8488	-.7068
		RS/RK	-.70556 [*]	.03514	.000	-.7766	-.6345
	Control	RS/ISD	-1.36556 [*]	.03514	.000	-1.4366	-1.2945
		Control/RP	.07778 [*]	.03514	.033	.0068	.1488
	RS	Control	.77778 [*]	.03514	.000	.7068	.8488
		RS/RK	.07222 [*]	.03514	.046	.0012	.1432
	RS	RS/ISD	-.58778 [*]	.03514	.000	-.6588	-.5168
		Control/RP	.85556 [*]	.03514	.000	.7845	.9266
	RS/RK	Control	.70556 [*]	.03514	.000	.6345	.7766
		RS	-.07222 [*]	.03514	.046	-.1432	-.0012
	RS/RK	RS/ISD	-.66000 [*]	.03514	.000	-.7310	-.5890
		Control/RP	.78333 [*]	.03514	.000	.7123	.8543
	RS/ISD	Control	1.36556 [*]	.03514	.000	1.2945	1.4366
		RS	.58778 [*]	.03514	.000	.5168	.6588
	RS/ISD	RS/RK	.66000 [*]	.03514	.000	.5890	.7310
		Control/RP	1.44333 [*]	.03514	.000	1.3723	1.5143
	Control/RP	Control	-.07778 [*]	.03514	.033	-.1488	-.0068
		RS	-.85556 [*]	.03514	.000	-.9266	-.7845
	Control/RP	RS/RK	-.78333 [*]	.03514	.000	-.8543	-.7123
		RS/ISD	-1.44333 [*]	.03514	.000	-1.5143	-1.3723

*. The mean difference is significant at the 0.05 level.

pH_Bread

Bread	N	Subset for alpha = 0.05				
		1	2	3	4	
Tukey HSD ^a	RS/ISD	9	4.2822			
	RS/RK	9		4.4178		
	RS	9			4.5122	
	Control	9			4.5778	
	Control/RP	9			4.6056	
	Sig.		1.000	1.000	1.000	.650

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

TTA_Bread

Bread	N	Subset for alpha = 0.05			
		1	2	3	
Tukey HSD ^a	Control/RP	9	3.4389		
	Control	9	3.5167		
	RS/RK	9		4.2222	
	RS	9		4.2944	
	RS/ISD	9		4.8822	
	Sig.		.196	.259	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

D.7 Statistical analysis of lactic and acetic acid concentration in bread dough (BD) samples before proofing (BP) and after proofing (AP) and bread samples of GF sweet potato sourdough breads

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Lacticacid_BP	Control	4	.4260	.00759	.00379	.4139	.4381	.42	.43
	RS	4	.2667	.00105	.00053	.2650	.2684	.27	.27
	RS/RK	4	.3076	.00158	.00079	.3051	.3101	.31	.31
	RS/ISD	4	.5284	.03616	.01808	.4709	.5860	.50	.57
	Control/RP	4	.5453	.01468	.00729	.5221	.5685	.53	.57
	Total	20	.4148	.11670	.02610	.3602	.4694	.27	.57
Lacticacid_AP	Control	4	.4887	.00701	.00350	.4775	.4998	.48	.50
	RS	4	.3173	.00769	.00385	.3051	.3295	.31	.32
	RS/RK	4	.3252	.00586	.00293	.3159	.3346	.32	.33
	RS/ISD	4	.5667	.05752	.02876	.4751	.6582	.51	.62
	Control/RP	4	.5647	.00958	.00479	.5494	.5799	.55	.57
	Total	20	.4525	.11613	.02597	.3982	.5069	.31	.62
Lacticacid_Bread	Control	4	.4678	.02717	.01358	.4246	.5110	.44	.50
	RS	4	.2672	.02524	.01262	.2271	.3074	.24	.29
	RS/RK	4	.2728	.02637	.01318	.2308	.3147	.25	.30
	RS/ISD	4	.3770	.01082	.00541	.3598	.3942	.36	.39
	Control/RP	4	.4447	.00551	.00275	.4360	.4535	.44	.45
	Total	20	.3659	.08802	.01968	.3247	.4071	.24	.50
Aceticacid_BP	Control	4	.2714	.00453	.00227	.2642	.2787	.27	.28
	RS	4	.2262	.00859	.00430	.2125	.2398	.21	.23
	RS/RK	4	.2604	.00431	.00215	.2536	.2673	.25	.26
	RS/ISD	4	.4656	.01075	.00538	.4485	.4828	.45	.48
	Control/RP	4	.3069	.00093	.00047	.3054	.3084	.31	.31
	Total	20	.3061	.08621	.01928	.2658	.3465	.21	.48
Aceticacid_AP	Control	4	.2925	.00259	.00129	.2884	.2966	.29	.30
	RS	4	.2375	.00288	.00144	.2329	.2421	.23	.24
	RS/RK	4	.2649	.00224	.00112	.2613	.2685	.26	.27
	RS/ISD	4	.4851	.00390	.00195	.4789	.4913	.48	.49
	Control/RP	4	.3139	.00623	.00312	.3040	.3239	.31	.32
	Total	20	.3188	.08937	.01998	.2770	.3606	.23	.49
Aceticacid_Bread	Control	4	.2577	.00552	.00276	.2489	.2664	.25	.27
	RS	4	.2386	.00258	.00129	.2345	.2427	.24	.24
	RS/RK	4	.2349	.00159	.00079	.2324	.2374	.23	.24
	RS/ISD	4	.3004	.00362	.00181	.2946	.3061	.30	.30
	Control/RP	4	.2206	.00844	.00422	.2071	.2340	.21	.23
	Total	20	.2504	.02870	.00642	.2370	.2639	.21	.30

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Lacticacid_BP	Between Groups	.254	4	.064	200.800	.000
	Within Groups	.005	15	.000		
	Total	.259	19			
Lacticacid_AP	Between Groups	.246	4	.061	86.662	.000
	Within Groups	.011	15	.001		
	Total	.256	19			
Lacticacid_Bread	Between Groups	.141	4	.035	79.218	.000
	Within Groups	.007	15	.000		
	Total	.147	19			
Aceticacid_BP	Between Groups	.141	4	.035	765.770	.000
	Within Groups	.001	15	.000		
	Total	.141	19			
Aceticacid_AP	Between Groups	.152	4	.038	2558.012	.000
	Within Groups	.000	15	.000		
	Total	.152	19			
Aceticacid_Bread	Between Groups	.015	4	.004	153.962	.000
	Within Groups	.000	15	.000		
	Total	.016	19			

Multiple Comparisons

Dependent Variable		(I) Breaddough_Bread	(J) Breaddough_Bread	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval	
							Lower Bound	Upper Bound
Lacticacid_BP	Tukey HSD	Control	RS	.15930 [†]	.01258	.000	.1205	.1981
			RS/RK	.11841 [†]	.01258	.000	.0796	.1572
			RS/ISD	-.10246 [†]	.01258	.000	-.1413	-.0636
			Control/RP	-.11932 [†]	.01258	.000	-.1582	-.0805
		RS	Control	-.15930 [†]	.01258	.000	-.1981	-.1205
			RS/RK	-.04089 [†]	.01258	.037	-.0797	-.0021
			RS/ISD	-.26176 [†]	.01258	.000	-.3006	-.2229
			Control/RP	-.27863 [†]	.01258	.000	-.3175	-.2398
		RS/RK	Control	-.11841 [†]	.01258	.000	-.1572	-.0796
			RS	.04089 [†]	.01258	.037	.0021	.0797
			RS/ISD	-.22086 [†]	.01258	.000	-.2597	-.1820
			Control/RP	-.23773 [†]	.01258	.000	-.2766	-.1989
		RS/ISD	Control	.10246 [†]	.01258	.000	.0636	.1413
			RS	.26176 [†]	.01258	.000	.2229	.3006
			RS/RK	.22086 [†]	.01258	.000	.1820	.2597
			Control/RP	-.01687	.01258	.671	-.0557	.0220
		Control/RP	Control	.11932 [†]	.01258	.000	.0805	.1582
			RS	.27863 [†]	.01258	.000	.2398	.3175
			RS/RK	.23773 [†]	.01258	.000	.1989	.2766
			RS/ISD	.01687	.01258	.671	-.0220	.0557
	LSD	Control	RS	.15930 [†]	.01258	.000	.1325	.1861
			RS/RK	.11841 [†]	.01258	.000	.0916	.1452
			RS/ISD	-.10246 [†]	.01258	.000	-.1293	-.0757
			Control/RP	-.11932 [†]	.01258	.000	-.1461	-.0925
		RS	Control	-.15930 [†]	.01258	.000	-.1861	-.1325
			RS/RK	-.04089 [†]	.01258	.005	-.0677	-.0141
			RS/ISD	-.26176 [†]	.01258	.000	-.2886	-.2350
			Control/RP	-.27863 [†]	.01258	.000	-.3054	-.2518
		RS/RK	Control	-.11841 [†]	.01258	.000	-.1452	-.0916
			RS	.04089 [†]	.01258	.005	.0141	.0677
			RS/ISD	-.22086 [†]	.01258	.000	-.2477	-.1941
			Control/RP	-.23773 [†]	.01258	.000	-.2645	-.2109
		RS/ISD	Control	.10246 [†]	.01258	.000	.0757	.1293
			RS	.26176 [†]	.01258	.000	.2350	.2886

Multiple Comparisons

Dependent Variable	(I) Breaddough Bread	(J) Breaddough Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Lacticacid_AP	Tukey HSD	Control	RS/RK	.22086 [*]	.01258	.000	.1941	.2477
			Control/RP	-.01687	.01258	.200	-.0437	.0099
			Control	.11932 [*]	.01258	.000	.0925	.1461
			RS	.27863 [*]	.01258	.000	.2518	.3054
			RS/RK	.23773 [*]	.01258	.000	.2109	.2645
		RS/ISD	.01687	.01258	.200	-.0099	.0437	
		RS	.17135 [*]	.01882	.000	.1132	.2295	
		RS/RK	.16341 [*]	.01882	.000	.1053	.2215	
		RS/ISD	-.07800 [*]	.01882	.007	-.1361	-.0199	
		Control/RP	-.07604 [*]	.01882	.008	-.1342	-.0179	
	RS	Control	-.17135 [*]	.01882	.000	-.2295	-.1132	
		RS/RK	-.00794	.01882	.993	-.0661	.0502	
		RS/ISD	-.24935 [*]	.01882	.000	-.3075	-.1912	
		Control/RP	-.24739 [*]	.01882	.000	-.3055	-.1893	
		RS/RK	Control	-.16341 [*]	.01882	.000	-.2215	-.1053
	RS/ISD	RS	.00794	.01882	.993	-.0502	.0661	
		RS/ISD	-.24141 [*]	.01882	.000	-.2995	-.1833	
		Control/RP	-.23945 [*]	.01882	.000	-.2976	-.1813	
		Control	.07800 [*]	.01882	.007	.0199	.1361	
		RS	.24935 [*]	.01882	.000	.1912	.3075	
Control/RP	RS/RK	.24141 [*]	.01882	.000	.1833	.2995		
	Control/RP	.00196	.01882	1.000	-.0562	.0601		
	Control	.07604 [*]	.01882	.008	.0179	.1342		
	RS	.24739 [*]	.01882	.000	.1893	.3055		
	RS/RK	.23945 [*]	.01882	.000	.1813	.2976		
LSD	Control	RS/ISD	RS/ISD	-.00196	.01882	1.000	-.0601	.0562
			Control	.17135 [*]	.01882	.000	.1312	.2115
			RS/RK	.16341 [*]	.01882	.000	.1233	.2035
			RS/ISD	-.07800 [*]	.01882	.001	-.1181	-.0379
			Control/RP	-.07604 [*]	.01882	.001	-.1162	-.0359
		RS	Control	-.17135 [*]	.01882	.000	-.2115	-.1312
			RS/RK	-.00794	.01882	.679	-.0481	.0322
			RS/ISD	-.24935 [*]	.01882	.000	-.2895	-.2092
			Control/RP	-.24739 [*]	.01882	.000	-.2875	-.2073
			RS/RK	Control	-.16341 [*]	.01882	.000	-.2035
	RS/ISD	RS	.00794	.01882	.679	-.0322	.0481	
		RS/ISD	-.24141 [*]	.01882	.000	-.2815	-.2013	
		Control/RP	-.23945 [*]	.01882	.000	-.2796	-.1993	
		Control	.07800 [*]	.01882	.001	.0379	.1181	
		RS	.24935 [*]	.01882	.000	.2092	.2895	
	Control/RP	RS/RK	.24141 [*]	.01882	.000	.2013	.2815	
		Control/RP	.00196	.01882	.918	-.0382	.0421	
		Control	.07604 [*]	.01882	.001	.0359	.1162	
		RS	.24739 [*]	.01882	.000	.2073	.2875	
		RS/RK	.23945 [*]	.01882	.000	.1993	.2796	
RS/ISD		-.00196	.01882	.918	-.0421	.0382		
Control		.20058 [*]	.01489	.000	.1546	.2466		
RS/RK		.19503 [*]	.01489	.000	.1490	.2410		
RS/ISD		.09076 [*]	.01489	.000	.0448	.1368		
Control/RP		.02304	.01489	.550	-.0229	.0690		
RS	Control	-.20058 [*]	.01489	.000	-.2466	-.1546		
	RS/RK	-.00555	.01489	.995	-.0515	.0404		
	RS/ISD	-.10981 [*]	.01489	.000	-.1558	-.0638		
	Control/RP	-.17754 [*]	.01489	.000	-.2235	-.1316		
	RS/RK	Control	-.19503 [*]	.01489	.000	-.2410	-.1490	
RS	.00555	.01489	.995	-.0404	.0515			

Multiple Comparisons

Dependent Variable	(I) Breaddough	Bread	(J) Breaddough	Bread	Mean Difference (I- J)	Std. Error	Sig.	95% Confidence Interval		
								Lower Bound	Upper Bound	
LSD	RS/ISD	Control/RP	RS/ISD		-.10426 [*]	.01489	.000	-.1502	-.0583	
			Control/RP		-.17199 [*]	.01489	.000	-.2180	-.1260	
		RS	Control		-.09076 [*]	.01489	.000	-.1368	-.0448	
			RS		.10981 [*]	.01489	.000	.0638	.1558	
			RS/RK		.10426 [*]	.01489	.000	.0583	.1502	
		Control/RP	Control/RP		-.06772 [*]	.01489	.003	-.1137	-.0217	
			Control		-.02304	.01489	.550	-.0690	.0229	
			RS		.17754 [*]	.01489	.000	.1316	.2235	
		Control/RP	RS/RK	Control		.17199 [*]	.01489	.000	.1260	.2180
				RS/ISD		.06772 [*]	.01489	.003	.0217	.1137
	RS				.20058 [*]	.01489	.000	.1688	.2323	
	RS/RK		Control		.19503 [*]	.01489	.000	.1633	.2268	
			RS/ISD		.09076 [*]	.01489	.000	.0590	.1225	
			Control/RP		.02304	.01489	.143	-.0087	.0548	
	Control		Control		-.20058 [*]	.01489	.000	-.2323	-.1688	
			RS/RK		-.00555	.01489	.715	-.0373	.0262	
			RS/ISD		-.10981 [*]	.01489	.000	-.1416	-.0781	
	Control/RP		Control/RP		-.17754 [*]	.01489	.000	-.2093	-.1458	
		Control		-.19503 [*]	.01489	.000	-.2268	-.1633		
		RS		.00555	.01489	.715	-.0262	.0373		
	RS/RK	RS/ISD	Control		-.10426 [*]	.01489	.000	-.1360	-.0725	
			Control/RP		-.17199 [*]	.01489	.000	-.2037	-.1402	
			Control		-.09076 [*]	.01489	.000	-.1225	-.0590	
		RS	RS		.10981 [*]	.01489	.000	.0781	.1416	
			RS/RK		.10426 [*]	.01489	.000	.0725	.1360	
			Control/RP		-.06772 [*]	.01489	.000	-.0995	-.0360	
		Control/RP	Control		-.02304	.01489	.143	-.0548	.0087	
			RS		.17754 [*]	.01489	.000	.1458	.2093	
			RS/RK		.17199 [*]	.01489	.000	.1402	.2037	
		RS/ISD	RS/ISD		.06772 [*]	.01489	.000	.0360	.0995	
	Control			.04526 [*]	.00479	.000	.0305	.0601		
	RS/RK			.01103	.00479	.197	-.0038	.0258		
	Aceticacid_BP	Tukey HSD	Control	RS/ISD		-.19420 [*]	.00479	.000	-.2090	-.1794
				Control/RP		-.03543 [*]	.00479	.000	-.0502	-.0206
				RS		-.04526 [*]	.00479	.000	-.0601	-.0305
				RS/RK		-.03423 [*]	.00479	.000	-.0490	-.0194
		RS	Control/RP	RS/ISD		-.23947 [*]	.00479	.000	-.2543	-.2247
				Control/RP		-.08069 [*]	.00479	.000	-.0955	-.0659
				Control		-.01103	.00479	.197	-.0258	.0038
				RS		.03423 [*]	.00479	.000	.0194	.0490
		RS/RK	RS/ISD	RS/ISD		-.20524 [*]	.00479	.000	-.2200	-.1904
				Control/RP		-.04646 [*]	.00479	.000	-.0613	-.0317
	Control				.19420 [*]	.00479	.000	.1794	.2090	
	RS				.23947 [*]	.00479	.000	.2247	.2543	
	RS/ISD	RS/RK	RS/RK		.20524 [*]	.00479	.000	.1904	.2200	
			Control/RP		.15878 [*]	.00479	.000	.1440	.1736	
			Control		.03543 [*]	.00479	.000	.0206	.0502	
			RS		.08069 [*]	.00479	.000	.0659	.0955	
	Control/RP	RS/ISD	RS/RK		.04646 [*]	.00479	.000	.0317	.0613	
			RS/ISD		-.15877 [*]	.00479	.000	-.1736	-.1440	
Control				.04526 [*]	.00479	.000	.0351	.0555		
RS/RK				.01103 [*]	.00479	.036	.0008	.0212		
LSD	Control	RS/ISD	RS/ISD		-.19420 [*]	.00479	.000	-.2044	-.1840	
			Control/RP		-.03543 [*]	.00479	.000	-.0456	-.0252	
			Control		-.04526 [*]	.00479	.000	-.0555	-.0351	
			RS/RK		-.03423 [*]	.00479	.000	-.0444	-.0240	

Multiple Comparisons

Dependent Variable	(I) Breaddough Bread	(J) Breaddough Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
		RS/ISD	RS/ISD	-.23947*	.00479	.000	-.2497	-.2293		
			Control/RP	-.08069*	.00479	.000	-.0909	-.0705		
		RS/RK	Control	-.01103*	.00479	.036	-.0212	-.0008		
			RS	.03423*	.00479	.000	.0240	.0444		
		RS/ISD	RS/ISD	-.20524*	.00479	.000	-.2154	-.1950		
			Control/RP	-.04646*	.00479	.000	-.0567	-.0363		
		RS/ISD	Control	.19420*	.00479	.000	.1840	.2044		
			RS	.23947*	.00479	.000	.2293	.2497		
			RS/RK	.20524*	.00479	.000	.1950	.2154		
			Control/RP	.15878*	.00479	.000	.1486	.1690		
		Control/RP	Control	.03543*	.00479	.000	.0252	.0456		
			RS	.08069*	.00479	.000	.0705	.0909		
			RS/RK	.04646*	.00479	.000	.0363	.0567		
			RS/ISD	-.15877*	.00479	.000	-.1690	-.1486		
		Aceticacid_AP	Tukey HSD	Control	RS	.05505*	.00272	.000	.0466	.0635
					RS/RK	.02763*	.00272	.000	.0192	.0360
RS/ISD	-.19256*				.00272	.000	-.2010	-.1842		
Control/RP	-.02141*				.00272	.000	-.0298	-.0130		
RS	Control			-.05505*	.00272	.000	-.0635	-.0466		
	RS/RK			-.02742*	.00272	.000	-.0358	-.0190		
	RS/ISD			-.24761*	.00272	.000	-.2560	-.2392		
	Control/RP			-.07646*	.00272	.000	-.0849	-.0681		
RS/RK	Control			-.02763*	.00272	.000	-.0360	-.0192		
	RS			.02742*	.00272	.000	.0190	.0358		
	RS/ISD			-.22019*	.00272	.000	-.2286	-.2118		
	Control/RP			-.04904*	.00272	.000	-.0574	-.0406		
RS/ISD	Control			.19256*	.00272	.000	.1842	.2010		
	RS			.24761*	.00272	.000	.2392	.2560		
	RS/RK			.22019*	.00272	.000	.2118	.2286		
	Control/RP			.17115*	.00272	.000	.1627	.1796		
Control/RP	Control		.02141*	.00272	.000	.0130	.0298			
	RS		.07646*	.00272	.000	.0681	.0849			
	RS/RK		.04904*	.00272	.000	.0406	.0574			
	RS/ISD		-.17115*	.00272	.000	-.1796	-.1627			
LSD	Control		RS	RS	.05505*	.00272	.000	.0493	.0609	
				RS/RK	.02763*	.00272	.000	.0218	.0334	
				RS/ISD	-.19256*	.00272	.000	-.1984	-.1868	
				Control/RP	-.02141*	.00272	.000	-.0272	-.0156	
			RS	Control	-.05505*	.00272	.000	-.0609	-.0493	
				RS/RK	-.02742*	.00272	.000	-.0332	-.0216	
				RS/ISD	-.24761*	.00272	.000	-.2534	-.2418	
				Control/RP	-.07646*	.00272	.000	-.0823	-.0707	
	RS/RK		Control	-.02763*	.00272	.000	-.0334	-.0218		
			RS	.02742*	.00272	.000	.0216	.0332		
			RS/ISD	-.22019*	.00272	.000	-.2260	-.2144		
			Control/RP	-.04904*	.00272	.000	-.0548	-.0432		
	RS/ISD	Control	.19256*	.00272	.000	.1868	.1984			
		RS	.24761*	.00272	.000	.2418	.2534			
		RS/RK	.22019*	.00272	.000	.2144	.2260			
		Control/RP	.17115*	.00272	.000	.1653	.1769			
Control/RP	Control	.02141*	.00272	.000	.0156	.0272				
	RS	.07646*	.00272	.000	.0707	.0823				
	RS/RK	.04904*	.00272	.000	.0432	.0548				
	RS/ISD	-.17115*	.00272	.000	-.1769	-.1653				
Aceticacid_Bread	Tukey HSD	Control	RS	.01910*	.00352	.001	.0082	.0300		
			RS/RK	.02276*	.00352	.000	.0119	.0336		

Multiple Comparisons

Dependent Variable	(I) Breaddough	Bread	(J) Breaddough	Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
								Lower Bound	Upper Bound
LSD	RS		RS/ISD		-.04269*	.00352	.000	-.0536	-.0318
			Control/RP		.03710*	.00352	.000	.0262	.0480
			Control		-.01910*	.00352	.001	-.0300	-.0082
			RS/RK		.00365	.00352	.834	-.0072	.0145
			RS/ISD		-.06180*	.00352	.000	-.0727	-.0509
	RS/RK		Control/RP		.01800*	.00352	.001	.0071	.0289
			Control		-.02276*	.00352	.000	-.0336	-.0119
			RS		-.00365	.00352	.834	-.0145	.0072
			RS/ISD		-.06546*	.00352	.000	-.0763	-.0546
			Control/RP		.01434*	.00352	.008	.0035	.0252
	RS/ISD		Control		.04269*	.00352	.000	.0318	.0536
			RS		.06180*	.00352	.000	.0509	.0727
			RS/RK		.06546*	.00352	.000	.0546	.0763
			Control/RP		.07979*	.00352	.000	.0689	.0907
			Control		-.03710*	.00352	.000	-.0480	-.0262
	Control/RP		RS		-.01800*	.00352	.001	-.0289	-.0071
			RS/RK		-.01434*	.00352	.008	-.0252	-.0035
			RS/ISD		-.07979*	.00352	.000	-.0907	-.0689
			RS		.01910*	.00352	.000	.0116	.0266
			RS/RK		.02276*	.00352	.000	.0152	.0303
Control		RS/ISD		-.04269*	.00352	.000	-.0502	-.0352	
		Control/RP		.03710*	.00352	.000	.0296	.0446	
		RS		-.01910*	.00352	.000	-.0266	-.0116	
		RS/RK		.00365	.00352	.316	-.0039	.0112	
		RS/ISD		-.06180*	.00352	.000	-.0693	-.0543	
RS		Control/RP		.01800*	.00352	.000	.0105	.0255	
		Control		-.02276*	.00352	.000	-.0303	-.0152	
		RS		-.00365	.00352	.316	-.0112	.0039	
		RS/ISD		-.06546*	.00352	.000	-.0730	-.0579	
		Control/RP		.01434*	.00352	.001	.0068	.0219	
RS/RK		RS/ISD		.04269*	.00352	.000	.0352	.0502	
		RS		.06180*	.00352	.000	.0543	.0693	
		RS/RK		.06546*	.00352	.000	.0579	.0730	
		Control/RP		.07979*	.00352	.000	.0723	.0873	
		Control		-.03710*	.00352	.000	-.0446	-.0296	
Control/RP		RS		-.01800*	.00352	.000	-.0255	-.0105	
		RS/RK		-.01434*	.00352	.001	-.0219	-.0068	
		RS/ISD		-.07979*	.00352	.000	-.0873	-.0723	

*. The mean difference is significant at the 0.05 level.

Lacticacid_BP

		Subset for alpha = 0.05			
Breaddough_Bread	N	1	2	3	4
Tukey HSD ^a	RS	4	.2667		
	RS/RK	4		.3076	
	Control	4			.4260
	RS/ISD	4			.5284
	Control/RP	4			.5453
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Lacticacid_Bread

		Subset for alpha = 0.05		
Breaddough_Bread	N	1	2	3
Tukey HSD ^a	RS	4	.2672	
	RS/RK	4	.2728	
	RS/ISD	4		.3770
	Control/RP	4		.4447
	Control	4		.4678
	Sig.		.995	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Lacticacid_AP

		Subset for alpha = 0.05		
Breaddough_Bread	N	1	2	3
Tukey HSD ^a	RS	4	.3173	
	RS/RK	4	.3252	
	Control	4		.4887
	Control/RP	4		.5647
	RS/ISD	4		.5667
	Sig.		.993	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Aceticacid_BP

		N	Subset for alpha = 0.05			
Breaddough_Bread			1	2	3	4
Tukey HSD ^a	RS	4	.2262			
	RS/RK	4		.2604		
	Control	4		.2714		
	Control/RP	4			.3069	
	RS/ISD	4				.4656
	Sig.		1.000	.197	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Aceticacid_Bread

		N	Subset for alpha = 0.05			
Breaddough_Bread			1	2	3	4
Tukey HSD ^a	Control/RP	4	.2206			
	RS/RK	4		.2349		
	RS	4		.2386		
	Control	4			.2577	
	RS/ISD	4				.3004
	Sig.		1.000	.834	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Aceticacid_AP

		N	Subset for alpha = 0.05				
Breaddough_Bread			1	2	3	4	5
Tukey HSD ^a	RS	4	.2375				
	RS/RK	4		.2649			
	Control	4			.2925		
	Control/RP	4				.3139	
	RS/ISD	4					.4851
	Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

D.8 Statistical analysis of FODMAP content of bread dough (BD) samples before proofing (BP) and after proofing (AP) and bread samples of GF sweet potato sourdough breads (g per 100 g as wet weight)

		Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Fructose_BD_BP	Control	2	.1705	.00276	.00195	.1458	.1953	.17	.17
	RS	2	.0850	.00014	.00010	.0838	.0863	.08	.09
	RS/RK	2	.0548	.00258	.00183	.0316	.0780	.05	.06
	RS/ISD	2	.0545	.00107	.00076	.0448	.0641	.05	.06
	Control/RP	2	.1884	.00857	.00606	.1114	.2653	.18	.19
	Total	10	.1106	.06075	.01921	.0672	.1541	.05	.19
Fructose_BD_AP	Control	2	.1549	.00091	.00064	.1467	.1631	.15	.16
	RS	2	.0648	.00093	.00065	.0565	.0731	.06	.07
	RS/RK	2	.0392	.00037	.00026	.0359	.0426	.04	.04
	RS/ISD	2	.0465	.00014	.00010	.0453	.0478	.05	.05
	Control/RP	2	.1617	.00090	.00064	.1536	.1698	.16	.16
	Total	10	.0934	.05656	.01789	.0530	.1339	.04	.16
Glucose_BD_BP	Control	2	.1479	.00389	.00275	.1130	.1829	.15	.15
	RS	2	.1307	.00109	.00077	.1209	.1405	.13	.13
	RS/RK	2	.1046	.00014	.00010	.1033	.1059	.10	.10
	RS/ISD	2	.1037	.00188	.00119	.0886	.1188	.10	.10
	Control/RP	2	.1027	.00092	.00065	.0944	.1110	.10	.10
	Total	10	.1179	.01936	.00612	.1041	.1318	.10	.15
Glucose_BD_AP	Control	2	.1256	.00323	.00229	.0965	.1546	.12	.13
	RS	2	.1335	.00251	.00177	.1109	.1560	.13	.14
	RS/RK	2	.0978	.00047	.00033	.0935	.1020	.10	.10
	RS/ISD	2	.0931	.00090	.00064	.0850	.1012	.09	.09
	Control/RP	2	.1037	.00121	.00086	.0928	.1145	.10	.10
	Total	10	.1107	.01684	.00533	.0987	.1228	.09	.14
Excessfructose_BD_BP	Control	2	.0226	.00113	.00080	.0124	.0328	.02	.02
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0857	.00949	.00671	.0004	.1709	.08	.09
	Total	10	.0216	.03512	.01110	-.0035	.0468	.00	.09
Excessfructose_BD_AP	Control	2	.0293	.00232	.00164	.0085	.0502	.03	.03
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0580	.00030	.00022	.0553	.0608	.06	.06
	Total	10	.0175	.02451	.00775	-.0001	.0350	.00	.06
Sorbitol_BD_BP	Control	2	.0042	.00013	.00009	.0031	.0053	.00	.00
	RS	2	.0036	.00006	.00004	.0031	.0041	.00	.00
	RS/RK	2	.0035	.00017	.00012	.0020	.0050	.00	.00
	RS/ISD	2	.0024	.00003	.00002	.0021	.0026	.00	.00
	Control/RP	2	.0032	.00008	.00006	.0025	.0039	.00	.00
	Total	10	.0034	.00063	.00020	.0029	.0038	.00	.00
Sorbitol_BD_AP	Control	2	.0042	.00002	.00001	.0041	.0043	.00	.00
	RS	2	.0035	.00008	.00006	.0028	.0042	.00	.00
	RS/RK	2	.0030	.00003	.00002	.0028	.0033	.00	.00
	RS/ISD	2	.0023	.00004	.00003	.0020	.0027	.00	.00
	Control/RP	2	.0032	.00008	.00006	.0024	.0039	.00	.00
	Total	10	.0032	.00065	.00021	.0028	.0037	.00	.00
Mannitol_BD_BP	Control	2	.0333	.00038	.00027	.0299	.0368	.03	.03
	RS	2	.0245	.00024	.00017	.0223	.0266	.02	.02
	RS/RK	2	.0249	.00029	.00020	.0224	.0275	.02	.03
	RS/ISD	2	.0284	.00006	.00004	.0278	.0290	.03	.03
	Control/RP	2	.0324	.00042	.00029	.0287	.0361	.03	.03
	Total	10	.0287	.00388	.00123	.0259	.0315	.02	.03

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Mannitol_BD_AP	Control	2	.0331	.00005	.00003	.0327	.0335	.03	.03
	RS	2	.0254	.00042	.00030	.0217	.0292	.03	.03
	RS/RK	2	.0256	.00047	.00033	.0214	.0298	.03	.03
	RS/ISD	2	.0293	.00001	.00001	.0292	.0294	.03	.03
	Control/RP	2	.0338	.00039	.00028	.0303	.0373	.03	.03
	Total	10	.0295	.00375	.00119	.0268	.0322	.03	.03
Raffinose_BD_BP	Control	2	.0017	.00007	.00005	.0010	.0023	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0009	.00002	.00001	.0007	.0010	.00	.00
	Total	10	.0005	.00070	.00022	.0000	.0010	.00	.00
Raffinose_BD_AP	Control	2	.0017	.00011	.00008	.0007	.0027	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	10	.0003	.00071	.00023	-.0002	.0008	.00	.00
Stachyose_BD_BP	Control	2	.0119	.00078	.00055	.0049	.0189	.01	.01
	RS	2	.0096	.00010	.00007	.0087	.0105	.01	.01
	RS/RK	2	.0039	.00028	.00020	.0013	.0064	.00	.00
	RS/ISD	2	.0049	.00014	.00010	.0036	.0062	.00	.00
	Control/RP	2	.0055	.00029	.00020	.0029	.0080	.01	.01
	Total	10	.0072	.00326	.00103	.0048	.0095	.00	.01
Stachyose_BD_AP	Control	2	.0134	.00054	.00038	.0086	.0183	.01	.01
	RS	2	.0121	.00017	.00012	.0105	.0136	.01	.01
	RS/RK	2	.0054	.00016	.00011	.0039	.0068	.01	.01
	RS/ISD	2	.0044	.00011	.00008	.0034	.0053	.00	.00
	Control/RP	2	.0054	.00010	.00007	.0045	.0062	.01	.01
	Total	10	.0081	.00404	.00128	.0052	.0110	.00	.01
Kestose_BD_BP	Control	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Kestose_BD_AP	Control	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Nystose_BD_BP	Control	2	.0389	.00194	.00137	.0215	.0563	.04	.04
	RS	2	.0657	.00213	.00151	.0466	.0849	.06	.07
	RS/RK	2	.0453	.00190	.00134	.0282	.0624	.04	.05
	RS/ISD	2	.0545	.00022	.00016	.0525	.0565	.05	.05
	Control/RP	2	.0228	.00058	.00041	.0177	.0280	.02	.02
	Total	10	.0455	.01530	.00484	.0345	.0564	.02	.07
Nystose_BD_AP	Control	2	.0361	.00099	.00070	.0272	.0450	.04	.04
	RS	2	.0763	.00064	.00045	.0705	.0821	.08	.08
	RS/RK	2	.0512	.00002	.00002	.0510	.0514	.05	.05
	RS/ISD	2	.0441	.00048	.00034	.0398	.0483	.04	.04
	Control/RP	2	.0236	.00004	.00003	.0232	.0239	.02	.02
	Total	10	.0482	.01856	.00587	.0330	.0595	.02	.08
Totalfructan_BD_BP	Control	2	.1770	.00635	.00449	.1200	.2340	.17	.18
	RS	2	.0622	.00137	.00097	.0498	.0745	.06	.06
	RS/RK	2	.0632	.00103	.00073	.0540	.0724	.06	.06
	RS/ISD	2	.0997	.00103	.00073	.0905	.1090	.10	.10
	Control/RP	2	.1685	.00368	.00260	.1354	.2015	.17	.17
	Total	10	.1141	.05256	.01662	.0765	.1517	.06	.18
Totalfructan_BD_AP	Control	2	.1436	.00103	.00073	.1343	.1529	.14	.14
	RS	2	.0561	.00139	.00098	.0436	.0686	.06	.06
	RS/RK	2	.0621	.00137	.00097	.0497	.0744	.06	.06
	RS/ISD	2	.0920	.00243	.00172	.0702	.1138	.09	.09
	Control/RP	2	.1652	.00237	.00168	.1439	.1865	.16	.17
	Total	10	.1038	.04600	.01455	.0709	.1367	.06	.17

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fructose_BD_BP	Between Groups	.033	4	.008	466.171	.000
	Within Groups	.000	5	.000		
	Total	.033	9			
Fructose_BD_AP	Between Groups	.029	4	.007	13520.245	.000
	Within Groups	.000	5	.000		
	Total	.029	9			
Glucose_BD_BP	Between Groups	.003	4	.001	209.385	.000
	Within Groups	.000	5	.000		
	Total	.003	9			
Glucose_BD_AP	Between Groups	.003	4	.001	164.509	.000
	Within Groups	.000	5	.000		
	Total	.003	9			
Excessfructose_BD_BP	Between Groups	.011	4	.003	150.590	.000
	Within Groups	.000	5	.000		
	Total	.011	9			
Excessfructose_BD_AP	Between Groups	.005	4	.001	1229.245	.000
	Within Groups	.000	5	.000		
	Total	.005	9			
Sorbitol_BD_BP	Between Groups	.000	4	.000	80.012	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Sorbitol_BD_AP	Between Groups	.000	4	.000	290.164	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Mannitol_BD_BP	Between Groups	.000	4	.000	364.091	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Mannitol_BD_AP	Between Groups	.000	4	.000	286.998	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Raffinose_BD_BP	Between Groups	.000	4	.000	981.132	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Raffinose_BD_AP	Between Groups	.000	4	.000	477.997	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Stachyose_BD_BP	Between Groups	.000	4	.000	147.618	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Stachyose_BD_AP	Between Groups	.000	4	.000	498.514	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Kestose_BD_BP	Between Groups	.000	4	.000		
	Within Groups	.000	5	.000		
	Total	.000	9			
Kestose_BD_AP	Between Groups	.000	4	.000		
	Within Groups	.000	5	.000		
	Total	.000	9			
Nystose_BD_BP	Between Groups	.002	4	.001	212.918	.000
	Within Groups	.000	5	.000		
	Total	.002	9			
Nystose_BD_AP	Between Groups	.003	4	.001	2378.010	.000
	Within Groups	.000	5	.000		
	Total	.003	9			
Totalfructan_BD_BP	Between Groups	.025	4	.006	536.529	.000
	Within Groups	.000	5	.000		
	Total	.025	9			
Totalfructan_BD_AP	Between Groups	.019	4	.005	1448.329	.000
	Within Groups	.000	5	.000		
	Total	.019	9			

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
Fructose_BD_BP	Tukey HSD	Control	RS	.08550 [*]	.00421	.000	.0686	.1024		
			RS/RK	.11576 [*]	.00421	.000	.0989	.1327		
			RS/ISD	.11605 [*]	.00421	.000	.0991	.1330		
			Control/RP	-.01784 [*]	.00421	.041	-.0348	-.0009		
		RS	Control	-.08550 [*]	.00421	.000	-.1024	-.0686		
			RS/RK	.03027 [*]	.00421	.004	.0134	.0472		
			RS/ISD	.03055 [*]	.00421	.004	.0136	.0475		
			Control/RP	-.10334 [*]	.00421	.000	-.1202	-.0864		
		RS/RK	Control	-.11576 [*]	.00421	.000	-.1327	-.0989		
			RS	-.03027 [*]	.00421	.004	-.0472	-.0134		
			RS/ISD	.00028	.00421	1.000	-.0166	.0172		
			Control/RP	-.13361 [*]	.00421	.000	-.1505	-.1167		
		RS/ISD	Control	-.11605 [*]	.00421	.000	-.1330	-.0991		
			RS	-.03055 [*]	.00421	.004	-.0475	-.0136		
			RS/RK	-.00028	.00421	1.000	-.0172	.0166		
			Control/RP	-.13389 [*]	.00421	.000	-.1508	-.1170		
		Control/RP	Control	.01784 [*]	.00421	.041	.0009	.0348		
			RS	.10334 [*]	.00421	.000	.0864	.1202		
			RS/RK	.13361 [*]	.00421	.000	.1167	.1505		
			RS/ISD	.13389 [*]	.00421	.000	.1170	.1508		
		LSD	Control	RS	.08550 [*]	.00421	.000	.0747	.0963	
				RS/RK	.11576 [*]	.00421	.000	.1049	.1266	
				RS/ISD	.11605 [*]	.00421	.000	.1052	.1269	
				Control/RP	-.01784 [*]	.00421	.008	-.0287	-.0070	
	RS		Control	-.08550 [*]	.00421	.000	-.0963	-.0747		
			RS/RK	.03027 [*]	.00421	.001	.0194	.0411		
			RS/ISD	.03055 [*]	.00421	.001	.0197	.0414		
			Control/RP	-.10334 [*]	.00421	.000	-.1142	-.0925		
	RS/RK		Control	-.11576 [*]	.00421	.000	-.1266	-.1049		
			RS	-.03027 [*]	.00421	.001	-.0411	-.0194		
			RS/ISD	.00028	.00421	.949	-.0105	.0111		
			Control/RP	-.13361 [*]	.00421	.000	-.1444	-.1228		
	RS/ISD		Control	-.11605 [*]	.00421	.000	-.1269	-.1052		
			RS	-.03055 [*]	.00421	.001	-.0414	-.0197		
			RS/RK	-.00028	.00421	.949	-.0111	.0105		
			Control/RP	-.13389 [*]	.00421	.000	-.1447	-.1231		
	Control/RP		Control	.01784 [*]	.00421	.008	.0070	.0287		
			RS	.10334 [*]	.00421	.000	.0925	.1142		
			RS/RK	.13361 [*]	.00421	.000	.1228	.1444		
			RS/ISD	.13389 [*]	.00421	.000	.1231	.1447		
	Fructose_BD_AP		Tukey HSD	Control	RS	.09009 [*]	.00073	.000	.0872	.0930
					RS/RK	.11568 [*]	.00073	.000	.1128	.1186
					RS/ISD	.10836 [*]	.00073	.000	.1054	.1113
					Control/RP	-.00680 [*]	.00073	.001	-.0097	-.0039
		RS		Control	-.09009 [*]	.00073	.000	-.0930	-.0872	
				RS/RK	.02559 [*]	.00073	.000	.0227	.0285	
				RS/ISD	.01827 [*]	.00073	.000	.0153	.0212	
				Control/RP	-.09689 [*]	.00073	.000	-.0998	-.0940	
RS/RK		Control		-.11568 [*]	.00073	.000	-.1186	-.1128		
		RS		-.02559 [*]	.00073	.000	-.0285	-.0227		
		RS/ISD		-.00733 [*]	.00073	.001	-.0103	-.0044		
		Control/RP		-.12249 [*]	.00073	.000	-.1254	-.1196		
RS/ISD		Control		-.10836 [*]	.00073	.000	-.1113	-.1054		
		RS		-.01827 [*]	.00073	.000	-.0212	-.0153		
		RS/RK		.00733 [*]	.00073	.001	.0044	.0103		
		Control/RP		-.11516 [*]	.00073	.000	-.1181	-.1122		
Control/RP		Control		.00680 [*]	.00073	.001	.0039	.0097		
		RS		.09689 [*]	.00073	.000	.0940	.0998		
		RS/RK		.12249 [*]	.00073	.000	.1196	.1254		
		RS/ISD		.11516 [*]	.00073	.000	.1122	.1181		
LSD		Control		RS	.09009 [*]	.00073	.000	.0882	.0920	
				RS/RK	.11568 [*]	.00073	.000	.1138	.1176	

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
		RS	RS/ISD	.10836*	.00073	.000	.1065	.1102
			Control/RP	-.00680	.00073	.000	-.0087	-.0049
			Control	-.09009*	.00073	.000	-.0920	-.0882
			RS/RK	.02559*	.00073	.000	.0237	.0275
			RS/ISD	.01827*	.00073	.000	.0164	.0201
		RS/RK	Control/RP	-.09689*	.00073	.000	-.0988	-.0950
			Control	-.11568*	.00073	.000	-.1176	-.1138
			RS	-.02559*	.00073	.000	-.0275	-.0237
			RS/ISD	-.00733*	.00073	.000	-.0092	-.0055
			Control/RP	-.12249*	.00073	.000	-.1244	-.1206
		RS/ISD	Control	-.10836*	.00073	.000	-.1102	-.1065
			RS	-.01827*	.00073	.000	-.0201	-.0164
			RS/RK	.00733*	.00073	.000	.0055	.0092
			Control/RP	-.11516*	.00073	.000	-.1170	-.1133
			Control	.00680	.00073	.000	.0049	.0087
		Control/RP	RS	.09689*	.00073	.000	.0950	.0988
			RS/RK	.12249*	.00073	.000	.1206	.1244
			RS/ISD	.11516*	.00073	.000	.1133	.1170
			Control	.00680	.00073	.000	.0049	.0087
			RS	.09689*	.00073	.000	.0950	.0988
Glucose_BD_BP	Tukey HSD	Control	RS	.01726*	.00200	.002	.0092	.0253
			RS/RK	.04337*	.00200	.000	.0353	.0514
			RS/ISD	.04426*	.00200	.000	.0362	.0523
			Control/RP	.04521*	.00200	.000	.0372	.0532
			Control	-.01726*	.00200	.002	-.0253	-.0092
		RS	RS/RK	.02611*	.00200	.000	.0181	.0341
			RS/ISD	.02700*	.00200	.000	.0190	.0350
			Control/RP	.02795*	.00200	.000	.0199	.0360
			Control	-.04337*	.00200	.000	-.0514	-.0353
			RS	-.02611*	.00200	.000	-.0341	-.0181
		RS/RK	RS/ISD	.00089	.00200	.990	-.0071	.0089
			Control/RP	.00184	.00200	.878	-.0062	.0099
			Control	-.04426*	.00200	.000	-.0523	-.0362
			RS	-.02700*	.00200	.000	-.0350	-.0190
			RS/RK	-.00089	.00200	.990	-.0089	.0071
		RS/ISD	Control/RP	.00096	.00200	.986	-.0071	.0090
			Control	-.04521*	.00200	.000	-.0532	-.0372
			RS	-.02795*	.00200	.000	-.0360	-.0199
			RS/RK	-.00184	.00200	.878	-.0099	.0062
			RS/ISD	-.00096	.00200	.986	-.0090	.0071
LSD	Control	RS	RS	.01726*	.00200	.000	.0121	.0224
			RS/RK	.04337*	.00200	.000	.0382	.0485
			RS/ISD	.04426*	.00200	.000	.0391	.0494
			Control/RP	.04521*	.00200	.000	.0401	.0504
			Control	-.01726*	.00200	.000	-.0224	-.0121
		RS	RS/RK	.02611*	.00200	.000	.0210	.0313
			RS/ISD	.02700*	.00200	.000	.0219	.0321
			Control/RP	.02795*	.00200	.000	.0228	.0331
			Control	-.04337*	.00200	.000	-.0485	-.0382
			RS	-.02611*	.00200	.000	-.0313	-.0210
		RS/RK	RS/ISD	.00089	.00200	.677	-.0043	.0060
			Control/RP	.00184	.00200	.399	-.0033	.0070
			Control	-.04426*	.00200	.000	-.0494	-.0391
			RS	-.02700*	.00200	.000	-.0321	-.0219
			RS/RK	-.00089	.00200	.677	-.0060	.0043
		RS/ISD	Control/RP	.00096	.00200	.653	-.0042	.0061
			Control	-.04521*	.00200	.000	-.0504	-.0401
			RS	-.02795*	.00200	.000	-.0331	-.0228
			RS/RK	-.00184	.00200	.399	-.0070	.0033
			RS/ISD	-.00096	.00200	.653	-.0061	.0042
Glucose_BD_AP	Tukey HSD	Control	RS	-.00791*	.00196	.049	-.0158	.0000
			RS/RK	.02781*	.00196	.000	.0199	.0357
			RS/ISD	.03249*	.00196	.000	.0246	.0404
			Control/RP	.02190*	.00196	.001	.0140	.0298

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS	Control	.00791*	.00196	.049	.0000	.0158		
		RS/RK	.03571*	.00196	.000	.0278	.0436		
		RS/ISD	.04040*	.00196	.000	.0325	.0483		
		Control/RP	.02981*	.00196	.000	.0219	.0377		
	RS/RK	Control	-.02781*	.00196	.000	-.0357	-.0199		
		RS	-.03571*	.00196	.000	-.0436	-.0278		
		RS/ISD	.00469	.00196	.256	-.0032	.0126		
		Control/RP	-.00591	.00196	.134	-.0138	.0020		
	RS/ISD	Control	-.03249*	.00196	.000	-.0404	-.0246		
		RS	-.04040*	.00196	.000	-.0483	-.0325		
		RS/RK	-.00469	.00196	.256	-.0126	.0032		
		Control/RP	-.01060*	.00196	.015	-.0185	-.0027		
	Control/RP	Control	-.02190*	.00196	.001	-.0298	-.0140		
		RS	-.02981*	.00196	.000	-.0377	-.0219		
		RS/RK	.00591	.00196	.134	-.0020	.0138		
		RS/ISD	.01060*	.00196	.015	.0027	.0185		
	LSD	Control	RS	-.00791*	.00196	.010	-.0130	-.0029	
			RS/RK	.02781*	.00196	.000	.0228	.0329	
			RS/ISD	.03249*	.00196	.000	.0274	.0375	
			Control/RP	.02190*	.00196	.000	.0169	.0269	
		RS	Control	.00791*	.00196	.010	.0029	.0130	
			RS/RK	.03571*	.00196	.000	.0307	.0408	
			RS/ISD	.04040*	.00196	.000	.0354	.0454	
			Control/RP	.02981*	.00196	.000	.0248	.0349	
		RS/RK	Control	-.02781*	.00196	.000	-.0329	-.0228	
			RS	-.03571*	.00196	.000	-.0408	-.0307	
			RS/ISD	.00469	.00196	.063	-.0004	.0097	
			Control/RP	-.00591*	.00196	.030	-.0110	-.0009	
		RS/ISD	Control	-.03249*	.00196	.000	-.0375	-.0274	
			RS	-.04040*	.00196	.000	-.0454	-.0354	
			RS/RK	-.00469	.00196	.063	-.0097	.0004	
			Control/RP	-.01060*	.00196	.003	-.0156	-.0056	
		Control/RP	Control	-.02190*	.00196	.000	-.0269	-.0169	
			RS	-.02981*	.00196	.000	-.0349	-.0248	
			RS/RK	.00591*	.00196	.030	.0009	.0110	
			RS/ISD	.01060*	.00196	.003	.0056	.0156	
		Excessfructose_BD_BP Tukey HSD	Control	RS	.02259*	.00427	.017	.0054	.0397
				RS/RK	.02259*	.00427	.017	.0054	.0397
				RS/ISD	.02259*	.00427	.017	.0054	.0397
				Control/RP	-.06306*	.00427	.000	-.0802	-.0459
RS			Control	-.02259*	.00427	.017	-.0397	-.0054	
			RS/RK	.00000	.00427	1.000	-.0171	.0171	
			RS/ISD	.00000	.00427	1.000	-.0171	.0171	
			Control/RP	-.08565*	.00427	.000	-.1028	-.0685	
RS/RK			Control	-.02259*	.00427	.017	-.0397	-.0054	
			RS	.00000	.00427	1.000	-.0171	.0171	
			RS/ISD	.00000	.00427	1.000	-.0171	.0171	
			Control/RP	-.08565*	.00427	.000	-.1028	-.0685	
RS/ISD			Control	-.02259*	.00427	.017	-.0397	-.0054	
			RS	.00000	.00427	1.000	-.0171	.0171	
			RS/RK	.00000	.00427	1.000	-.0171	.0171	
			Control/RP	-.08565*	.00427	.000	-.1028	-.0685	
Control/RP			Control	.06306*	.00427	.000	.0459	.0802	
			RS	.08565*	.00427	.000	.0685	.1028	
			RS/RK	.08565*	.00427	.000	.0685	.1028	
			RS/ISD	.08565*	.00427	.000	.0685	.1028	
LSD	Control		RS	.02259*	.00427	.003	.0116	.0336	
			RS/RK	.02259*	.00427	.003	.0116	.0336	
			RS/ISD	.02259*	.00427	.003	.0116	.0336	
			Control/RP	-.06306*	.00427	.000	-.0740	-.0521	
	RS		Control	-.02259*	.00427	.003	-.0336	-.0116	
			RS/RK	.00000	.00427	1.000	-.0110	.0110	

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS/RK	RS/ISD	.00000	.00427	1.000	-.0110	.0110		
		Control/RP	-.08565*	.00427	.000	-.0966	-.0747		
		Control	-.02259*	.00427	.003	-.0336	-.0116		
		RS	.00000	.00427	1.000	-.0110	.0110		
	RS/ISD	RS/ISD	.00000	.00427	1.000	-.0110	.0110		
		Control/RP	-.08565*	.00427	.000	-.0966	-.0747		
		Control	-.02259*	.00427	.003	-.0336	-.0116		
		RS	.00000	.00427	1.000	-.0110	.0110		
	Control/RP	Control/RP	.06306*	.00427	.000	.0521	.0740		
		RS	.08565*	.00427	.000	.0747	.0966		
		RS/RK	.08565*	.00427	.000	.0747	.0966		
		RS/ISD	.08565*	.00427	.000	.0747	.0966		
	Excessfructose_BD_AP	Tukey HSD	Control	RS	.02933*	.00105	.000	.0251	.0335
				RS/RK	.02933*	.00105	.000	.0251	.0335
				RS/ISD	.02933*	.00105	.000	.0251	.0335
				Control/RP	-.02870*	.00105	.000	-.0329	-.0245
RS		Control	-.02933*	.00105	.000	-.0335	-.0251		
		RS/RK	.00000	.00105	1.000	-.0042	.0042		
		RS/ISD	.00000	.00105	1.000	-.0042	.0042		
		Control/RP	-.05803*	.00105	.000	-.0622	-.0538		
RS/RK		Control	-.02933*	.00105	.000	-.0335	-.0251		
		RS	.00000	.00105	1.000	-.0042	.0042		
		RS/ISD	.00000	.00105	1.000	-.0042	.0042		
		Control/RP	-.05803*	.00105	.000	-.0622	-.0538		
RS/ISD		Control	-.02933*	.00105	.000	-.0335	-.0251		
		RS	.00000	.00105	1.000	-.0042	.0042		
		RS/RK	.00000	.00105	1.000	-.0042	.0042		
		Control/RP	-.05803*	.00105	.000	-.0622	-.0538		
Control/RP	Control	.02870*	.00105	.000	.0245	.0329			
	RS	.05803*	.00105	.000	.0538	.0622			
	RS/RK	.05803*	.00105	.000	.0538	.0622			
	RS/ISD	.05803*	.00105	.000	.0538	.0622			
LSD	Control	RS	.02933*	.00105	.000	.0266	.0320		
		RS/RK	.02933*	.00105	.000	.0266	.0320		
		RS/ISD	.02933*	.00105	.000	.0266	.0320		
		Control/RP	-.02870*	.00105	.000	-.0314	-.0260		
	RS	Control	-.02933*	.00105	.000	-.0320	-.0266		
		RS/RK	.00000	.00105	1.000	-.0027	.0027		
		RS/ISD	.00000	.00105	1.000	-.0027	.0027		
		Control/RP	-.05803*	.00105	.000	-.0607	-.0553		
	RS/RK	Control	-.02933*	.00105	.000	-.0320	-.0266		
		RS	.00000	.00105	1.000	-.0027	.0027		
		RS/ISD	.00000	.00105	1.000	-.0027	.0027		
		Control/RP	-.05803*	.00105	.000	-.0607	-.0553		
	RS/ISD	Control	-.02933*	.00105	.000	-.0320	-.0266		
		RS	.00000	.00105	1.000	-.0027	.0027		
		RS/RK	.00000	.00105	1.000	-.0027	.0027		
		Control/RP	-.05803*	.00105	.000	-.0607	-.0553		
Control/RP	Control	.02870*	.00105	.000	.0260	.0314			
	RS	.05803*	.00105	.000	.0553	.0607			
	RS/RK	.05803*	.00105	.000	.0553	.0607			
	RS/ISD	.05803*	.00105	.000	.0553	.0607			
Sorbitol_BD_BP	Tukey HSD	Control	RS	.00061*	.00010	.011	.0002	.0010	
			RS/RK	.00069*	.00010	.006	.0003	.0011	
			RS/ISD	.00180*	.00010	.000	.0014	.0022	
			Control/RP	.00101*	.00010	.001	.0006	.0014	
	RS	Control	-.00061*	.00010	.011	-.0010	-.0002		
		RS/RK	.00008	.00010	.921	-.0003	.0005		
		RS/ISD	.00119*	.00010	.000	.0008	.0016		
		Control/RP	.00040	.00010	.061	.0000	.0008		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval		
						Lower Bound	Upper Bound	
Sorbitol_BD_AP	LSD	RS/RK	Control	-.00069 [*]	.00010	.006	-.0011	-.0003
			RS	-.00008	.00010	.921	-.0005	.0003
			RS/ISD	.00111 [*]	.00010	.001	.0007	.0015
		RS/ISD	Control/RP	.00031	.00010	.134	-.0001	.0007
			Control	-.00180 [*]	.00010	.000	-.0022	-.0014
			RS	-.00119 [*]	.00010	.000	-.0016	-.0008
		Control/RP	RS/RK	-.00111 [*]	.00010	.001	-.0015	-.0007
			Control/RP	-.00080 [*]	.00010	.003	-.0012	-.0004
			Control	-.00101 [*]	.00010	.001	-.0014	-.0006
		RS	RS	-.00040	.00010	.061	-.0008	.0000
			RS/RK	-.00031	.00010	.134	-.0007	.0001
			RS/ISD	.00080 [*]	.00010	.003	.0004	.0012
	Tukey HSD	Control	RS	.00061 [*]	.00010	.002	.0003	.0009
			RS/RK	.00069 [*]	.00010	.001	.0004	.0010
			RS/ISD	.00180 [*]	.00010	.000	.0015	.0021
		RS	Control/RP	.00101 [*]	.00010	.000	.0007	.0013
			Control	-.00061 [*]	.00010	.002	-.0009	-.0003
			RS/RK	.00008	.00010	.461	-.0002	.0004
		RS/RK	RS/ISD	.00119 [*]	.00010	.000	.0009	.0015
			Control/RP	.00040 [*]	.00010	.013	.0001	.0007
			Control	-.00069 [*]	.00010	.001	-.0010	-.0004
		RS/ISD	RS	-.00008	.00010	.461	-.0004	.0002
			RS/ISD	.00111 [*]	.00010	.000	.0008	.0014
			Control/RP	.00031 [*]	.00010	.030	.0000	.0006
	Control/RP	Control	-.00180 [*]	.00010	.000	-.0021	-.0015	
		RS	-.00119 [*]	.00010	.000	-.0015	-.0009	
		RS/RK	-.00111 [*]	.00010	.000	-.0014	-.0008	
	LSD	Control	Control/RP	-.00080 [*]	.00010	.001	-.0011	-.0005
			Control	-.00101 [*]	.00010	.000	-.0013	-.0007
			RS	-.00040 [*]	.00010	.013	-.0007	-.0001
		RS	RS/RK	-.00031 [*]	.00010	.030	-.0006	.0000
			RS/ISD	.00080 [*]	.00010	.001	.0005	.0011
			Control	.00069 [*]	.00006	.000	.0005	.0009
		RS	RS/RK	.00116 [*]	.00006	.000	.0009	.0014
			RS/ISD	.00188 [*]	.00006	.000	.0017	.0021
			Control/RP	.00102 [*]	.00006	.000	.0008	.0012
		RS/RK	Control	-.00069 [*]	.00006	.000	-.0009	-.0005
			RS	.00047 [*]	.00006	.002	.0002	.0007
			RS/ISD	.00119 [*]	.00006	.000	.0010	.0014
	RS/ISD	Control/RP	.00033 [*]	.00006	.012	.0001	.0006	
		Control	-.00116 [*]	.00006	.000	-.0014	-.0009	
		RS	-.00047 [*]	.00006	.002	-.0007	-.0002	
	Control/RP	RS/ISD	.00072 [*]	.00006	.000	.0005	.0010	
		Control/RP	-.00014	.00006	.241	-.0004	.0001	
		Control	-.00188 [*]	.00006	.000	-.0021	-.0017	
	RS	RS	-.00119 [*]	.00006	.000	-.0014	-.0010	
		RS/RK	-.00072 [*]	.00006	.000	-.0010	-.0005	
		Control/RP	-.00086 [*]	.00006	.000	-.0011	-.0006	
RS/RK	Control	-.00102 [*]	.00006	.000	-.0012	-.0008		
	RS	-.00033 [*]	.00006	.012	-.0006	-.0001		
	RS/RK	.00014	.00006	.241	-.0001	.0004		
LSD	Control	RS/ISD	.00086 [*]	.00006	.000	.0006	.0011	
		Control	.00069 [*]	.00006	.000	.0005	.0008	
		RS/RK	.00116 [*]	.00006	.000	.0010	.0013	
	RS	RS/ISD	.00188 [*]	.00006	.000	.0017	.0020	
		Control/RP	.00102 [*]	.00006	.000	.0009	.0012	
		Control	-.00069 [*]	.00006	.000	-.0008	-.0005	
	RS/RK	RS	.00047 [*]	.00006	.000	.0003	.0006	
		RS/ISD	.00119 [*]	.00006	.000	.0010	.0013	
		Control/RP	.00033 [*]	.00006	.002	.0002	.0005	
	Control	Control	-.00116 [*]	.00006	.000	-.0013	-.0010	
		RS	-.00047 [*]	.00006	.000	-.0006	-.0003	

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
		RS/ISD	RS/ISD	.00072 [*]	.00006	.000	.0006	.0009		
			Control/RP	-.00014	.00006	.058	-.0003	.0000		
		RS/ISD	Control	-.00188 [*]	.00006	.000	-.0020	-.0017		
			RS	-.00119 [*]	.00006	.000	-.0013	-.0010		
			RS/RK	-.00072 [*]	.00006	.000	-.0009	-.0006		
			Control/RP	-.00088 [*]	.00006	.000	-.0010	-.0007		
		Control/RP	Control	-.00102 [*]	.00006	.000	-.0012	-.0009		
			RS	-.00033 [*]	.00006	.002	-.0005	-.0002		
			RS/RK	.00014	.00006	.058	.0000	.0003		
			RS/ISD	.00086 [*]	.00006	.000	.0007	.0010		
		Mannitol_BD_BP	Tukey HSD	Control	RS	.00886 [*]	.00030	.000	.0076	.0101
					RS/RK	.00841 [*]	.00030	.000	.0072	.0096
RS/ISD	.00493 [*]				.00030	.000	.0037	.0061		
Control/RP	.00092				.00030	.134	-.0003	.0021		
RS	Control			-.00886 [*]	.00030	.000	-.0101	-.0076		
	RS/RK			-.00046	.00030	.611	-.0017	.0008		
	RS/ISD			-.00393 [*]	.00030	.000	-.0052	-.0027		
	Control/RP			-.00794 [*]	.00030	.000	-.0092	-.0067		
RS/RK	Control			-.00841 [*]	.00030	.000	-.0096	-.0072		
	RS			.00046	.00030	.611	-.0008	.0017		
	RS/ISD			-.00348 [*]	.00030	.000	-.0047	-.0023		
	Control/RP			-.00749 [*]	.00030	.000	-.0087	-.0063		
RS/ISD	Control			-.00493 [*]	.00030	.000	-.0061	-.0037		
	RS			.00393 [*]	.00030	.000	.0027	.0052		
	RS/RK	.00348 [*]	.00030	.000	.0023	.0047				
	Control/RP	-.00401 [*]	.00030	.000	-.0052	-.0028				
Control/RP	Control	-.00092	.00030	.134	-.0021	.0003				
	RS	.00794 [*]	.00030	.000	.0067	.0092				
	RS/RK	.00749 [*]	.00030	.000	.0063	.0087				
	RS/ISD	.00401 [*]	.00030	.000	.0028	.0052				
LSD	LSD	Control	RS	.00886 [*]	.00030	.000	.0081	.0096		
			RS/RK	.00841 [*]	.00030	.000	.0076	.0092		
			RS/ISD	.00493 [*]	.00030	.000	.0041	.0057		
			Control/RP	.00092 [*]	.00030	.030	.0001	.0017		
		RS	Control	-.00886 [*]	.00030	.000	-.0096	-.0081		
			RS/RK	-.00046	.00030	.198	-.0012	.0003		
			RS/ISD	-.00393 [*]	.00030	.000	-.0047	-.0032		
			Control/RP	-.00794 [*]	.00030	.000	-.0087	-.0072		
		RS/RK	Control	-.00841 [*]	.00030	.000	-.0092	-.0076		
			RS	.00046	.00030	.198	-.0003	.0012		
			RS/ISD	-.00348 [*]	.00030	.000	-.0043	-.0027		
			Control/RP	-.00749 [*]	.00030	.000	-.0083	-.0067		
		RS/ISD	Control	-.00493 [*]	.00030	.000	-.0057	-.0041		
			RS	.00393 [*]	.00030	.000	.0032	.0047		
RS/RK	.00348 [*]		.00030	.000	.0027	.0043				
Control/RP	-.00401 [*]		.00030	.000	-.0048	-.0032				
Control/RP	Control	-.00092 [*]	.00030	.030	-.0017	-.0001				
	RS	.00794 [*]	.00030	.000	.0072	.0087				
	RS/RK	.00749 [*]	.00030	.000	.0067	.0083				
	RS/ISD	.00401 [*]	.00030	.000	.0032	.0048				
Mannitol_BD_AP	Tukey HSD	Control	RS	.00768 [*]	.00033	.000	.0063	.0090		
			RS/RK	.00747 [*]	.00033	.000	.0061	.0088		
			RS/ISD	.00379 [*]	.00033	.000	.0025	.0051		
			Control/RP	-.00071	.00033	.331	-.0020	.0006		
		RS	Control	-.00768 [*]	.00033	.000	-.0090	-.0063		
			RS/RK	-.00021	.00033	.962	-.0015	.0011		
			RS/ISD	-.00369 [*]	.00033	.000	-.0052	-.0026		
			Control/RP	-.00839 [*]	.00033	.000	-.0097	-.0071		
		RS/RK	Control	-.00747 [*]	.00033	.000	-.0088	-.0061		
			RS	.00021	.00033	.962	-.0011	.0015		
			RS/ISD	-.00368 [*]	.00033	.001	-.0050	-.0024		
			Control/RP	-.00818 [*]	.00033	.000	-.0095	-.0068		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval					
						Lower Bound	Upper Bound				
	LSD	RS/ISD	Control	-.00379 [*]	.00033	.000	-.0051	-.0025			
			RS	.00389 [*]	.00033	.000	.0026	.0052			
			RS/RK	.00368 [*]	.00033	.001	.0024	.0050			
			Control/RP	-.00449 [*]	.00033	.000	-.0058	-.0032			
		Control/RP	Control	.00071	.00033	.331	-.0006	.0020			
			RS	.00839 [*]	.00033	.000	.0071	.0097			
			RS/RK	.00818 [*]	.00033	.000	.0068	.0095			
			RS/ISD	.00449 [*]	.00033	.000	.0032	.0058			
		RS	Control	RS	.00768 [*]	.00033	.000	.0068	.0085		
				RS/RK	.00747 [*]	.00033	.000	.0066	.0083		
				RS/ISD	.00379 [*]	.00033	.000	.0029	.0046		
				Control/RP	-.00071	.00033	.086	-.0016	.0001		
	RS		Control	-.00768 [*]	.00033	.000	-.0085	-.0068			
			RS/RK	-.00021	.00033	.553	-.0011	.0006			
			RS/ISD	-.00389 [*]	.00033	.000	-.0047	-.0030			
			Control/RP	-.00839 [*]	.00033	.000	-.0092	-.0075			
	RS/RK		Control	-.00747 [*]	.00033	.000	-.0083	-.0066			
			RS	.00021	.00033	.553	-.0006	.0011			
			RS/ISD	-.00368 [*]	.00033	.000	-.0045	-.0028			
			Control/RP	-.00818 [*]	.00033	.000	-.0090	-.0073			
	RS/ISD	Control	RS	-.00379 [*]	.00033	.000	-.0046	-.0029			
			RS	.00389 [*]	.00033	.000	.0030	.0047			
			RS/RK	.00368 [*]	.00033	.000	.0028	.0045			
			Control/RP	-.00449 [*]	.00033	.000	-.0053	-.0036			
		Control/RP	Control	.00071	.00033	.086	-.0001	.0016			
			RS	.00839 [*]	.00033	.000	.0075	.0092			
			RS/RK	.00818 [*]	.00033	.000	.0073	.0090			
			RS/ISD	.00449 [*]	.00033	.000	.0036	.0053			
		Raffinose_BD_BP	Tukey HSD	Control	RS	RS	.00165 [*]	.00003	.000	.0015	.0018
						RS/RK	.00165 [*]	.00003	.000	.0015	.0018
						RS/ISD	.00165 [*]	.00003	.000	.0015	.0018
						Control/RP	.00077 [*]	.00003	.000	.0006	.0009
	RS				Control	-.00165 [*]	.00003	.000	-.0018	-.0015	
					RS/RK	.00000	.00003	1.000	-.0001	.0001	
					RS/ISD	.00000	.00003	1.000	-.0001	.0001	
					Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0007	
	RS/RK				Control	-.00165 [*]	.00003	.000	-.0018	-.0015	
					RS	.00000	.00003	1.000	-.0001	.0001	
					RS/ISD	.00000	.00003	1.000	-.0001	.0001	
					Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0007	
	RS/ISD			Control	-.00165 [*]	.00003	.000	-.0018	-.0015		
				RS	.00000	.00003	1.000	-.0001	.0001		
				RS/RK	.00000	.00003	1.000	-.0001	.0001		
				Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0007		
	Control/RP			Control	-.00077 [*]	.00003	.000	-.0009	-.0006		
				RS	.00088 [*]	.00003	.000	.0007	.0010		
				RS/RK	.00088 [*]	.00003	.000	.0007	.0010		
				RS/ISD	.00088 [*]	.00003	.000	.0007	.0010		
LSD	Control			RS	.00165 [*]	.00003	.000	.0016	.0017		
				RS/RK	.00165 [*]	.00003	.000	.0016	.0017		
				RS/ISD	.00165 [*]	.00003	.000	.0016	.0017		
				Control/RP	.00077 [*]	.00003	.000	.0007	.0009		
	RS			Control	-.00165 [*]	.00003	.000	-.0017	-.0016		
				RS/RK	.00000	.00003	1.000	-.0001	.0001		
				RS/ISD	.00000	.00003	1.000	-.0001	.0001		
				Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0008		
	RS/RK			Control	-.00165 [*]	.00003	.000	-.0017	-.0016		
				RS	.00000	.00003	1.000	-.0001	.0001		
				RS/ISD	.00000	.00003	1.000	-.0001	.0001		
				Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0008		
RS/ISD	Control			-.00165 [*]	.00003	.000	-.0017	-.0016			
	RS			.00000	.00003	1.000	-.0001	.0001			
	RS/RK			.00000	.00003	1.000	-.0001	.0001			
	Control/RP			-.00088 [*]	.00003	.000	-.0010	-.0008			

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Raffinose_BD_AP	Tukey HSD	Control	RS/RK	.0000	.00003	1.000	-.0001	.0001
			Control/RP	-.00088 [*]	.00003	.000	-.0010	-.0008
			Control	-.00077 [*]	.00003	.000	-.0009	-.0007
			RS	.00088 [*]	.00003	.000	.0008	.0010
			RS/RK	.00088 [*]	.00003	.000	.0008	.0010
		RS/ISD	.00088 [*]	.00003	.000	.0008	.0010	
		RS	Control	-.00169 [*]	.00005	.000	-.0019	-.0015
			RS/RK	.00169 [*]	.00005	.000	.0015	.0019
			RS/ISD	.00169 [*]	.00005	.000	.0015	.0019
			Control/RP	.00169 [*]	.00005	.000	.0015	.0019
	Control		-.00169 [*]	.00005	.000	-.0019	-.0015	
	LSD	Control	RS	.00169 [*]	.00005	.000	.0016	.0018
			RS/RK	.00169 [*]	.00005	.000	.0016	.0018
			RS/ISD	.00169 [*]	.00005	.000	.0016	.0018
			Control/RP	.00169 [*]	.00005	.000	.0016	.0018
			Control	-.00169 [*]	.00005	.000	-.0018	-.0016
		RS	Control	-.00169 [*]	.00005	.000	-.0018	-.0016
			RS/RK	.00000	.00005	1.000	-.0001	.0001
			RS/ISD	.00000	.00005	1.000	-.0001	.0001
			Control/RP	.00000	.00005	1.000	-.0001	.0001
Control			-.00169 [*]	.00005	.000	-.0018	-.0016	
RS/RK	Control	-.00169 [*]	.00005	.000	-.0018	-.0016		
	RS	.00000	.00005	1.000	-.0001	.0001		
	RS/ISD	.00000	.00005	1.000	-.0001	.0001		
	Control/RP	.00000	.00005	1.000	-.0001	.0001		
	Control	-.00169 [*]	.00005	.000	-.0018	-.0016		
RS/ISD	Control	-.00169 [*]	.00005	.000	-.0018	-.0016		
	RS	.00000	.00005	1.000	-.0001	.0001		
	RS/RK	.00000	.00005	1.000	-.0001	.0001		
	Control/RP	.00000	.00005	1.000	-.0001	.0001		
	Control	-.00169 [*]	.00005	.000	-.0018	-.0016		
Stachyose_BD_BP	Tukey HSD	Control	RS	.00231 [†]	.00040	.012	.0007	.0039
			RS/RK	.00804 [*]	.00040	.000	.0064	.0096
			RS/ISD	.00703 [*]	.00040	.000	.0054	.0086
			Control/RP	.00644 [*]	.00040	.000	.0048	.0081
			Control	-.00231 [†]	.00040	.012	-.0039	-.0007
		RS	Control	-.00231 [†]	.00040	.012	-.0039	-.0007
			RS/RK	.00573 [†]	.00040	.000	.0041	.0073
			RS/ISD	.00472 [*]	.00040	.000	.0031	.0063
			Control/RP	.00413 [*]	.00040	.001	.0025	.0057
			Control	-.00231 [†]	.00040	.012	-.0039	-.0007
RS/RK	Control	-.00804 [*]	.00040	.000	-.0096	-.0064		
	RS	-.00573 [†]	.00040	.000	-.0073	-.0041		
	RS/ISD	-.00100	.00040	.226	-.0026	.0006		
	Control/RP	-.00159	.00040	.052	-.0032	.0000		
	Control	-.00231 [†]	.00040	.000	-.0039	-.0007		
RS/ISD	Control	-.00703 [*]	.00040	.000	-.0086	-.0054		
	RS	-.00472 [*]	.00040	.000	-.0063	-.0031		
	RS/RK	.00100	.00040	.226	-.0006	.0006		
	Control/RP	-.00059	.00040	.617	-.0022	.0010		
	Control	-.00644 [*]	.00040	.000	-.0081	-.0048		
Control/RP	Control	-.00644 [*]	.00040	.000	-.0081	-.0048		
	RS	-.00413 [*]	.00040	.001	-.0057	-.0025		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval				
						Lower Bound	Upper Bound			
	LSD	Control	RS/RK	.00159	.00040	.052	.0000	.0032		
			RS/ISD	.00059	.00040	.617	-.0010	.0022		
			RS	.00231 [*]	.00040	.002	.0013	.0033		
			Control/RP	.00804 [*]	.00040	.000	.0070	.0091		
		RS	RS/RK	.00703 [*]	.00040	.000	.0060	.0081		
			Control/RP	.00644 [*]	.00040	.000	.0054	.0075		
			Control	-.00231 [*]	.00040	.002	-.0033	-.0013		
			RS/RK	.00573 [*]	.00040	.000	.0047	.0068		
		RS/RK	RS/ISD	.00472 [*]	.00040	.000	.0037	.0058		
			Control/RP	.00413 [*]	.00040	.000	.0031	.0052		
			Control	-.00804 [*]	.00040	.000	-.0091	-.0070		
			RS	-.00573 [*]	.00040	.000	-.0068	-.0047		
		RS/ISD	RS/ISD	-.00100	.00040	.054	-.0020	.0000		
			Control/RP	-.00159 [*]	.00040	.011	-.0026	-.0006		
			Control	-.00703 [*]	.00040	.000	-.0081	-.0060		
			RS	-.00472 [*]	.00040	.000	-.0058	-.0037		
		Control/RP	RS/RK	.00100	.00040	.054	.0000	.0020		
			Control/RP	-.00059	.00040	.201	-.0016	.0004		
			Control	-.00644 [*]	.00040	.000	-.0075	-.0054		
			RS	-.00413 [*]	.00040	.000	-.0052	-.0031		
		Stachyose_BD_AP	Tukey HSD	Control	RS/RK	.00159 [*]	.00040	.011	.0006	.0026
					RS/ISD	.00059	.00040	.201	-.0004	.0016
					RS	.00135 [*]	.00027	.021	.0003	.0024
					Control/RP	.00807 [*]	.00027	.000	.0070	.0092
				RS	RS/RK	.00807 [*]	.00027	.000	.0080	.0101
					Control/RP	.00807 [*]	.00027	.000	.0070	.0092
					Control	-.00135 [*]	.00027	.021	-.0024	-.0003
					RS/RK	.00672 [*]	.00027	.000	.0056	.0078
				RS/RK	RS/ISD	.00771 [*]	.00027	.000	.0066	.0088
					Control/RP	.00672 [*]	.00027	.000	.0056	.0078
					Control	-.00807 [*]	.00027	.000	-.0092	-.0070
					RS	-.00672 [*]	.00027	.000	-.0078	-.0056
				RS/ISD	RS/ISD	.00099	.00027	.071	-.0001	.0021
					Control/RP	.00000	.00027	1.000	-.0011	.0011
					Control	-.00905 [*]	.00027	.000	-.0101	-.0080
					RS	-.00771 [*]	.00027	.000	-.0088	-.0066
				Control/RP	RS/RK	-.00099	.00027	.071	-.0021	.0001
					Control/RP	-.00099	.00027	.071	-.0021	.0001
					Control	-.00807 [*]	.00027	.000	-.0092	-.0070
					RS	-.00672 [*]	.00027	.000	-.0078	-.0056
LSD	Control			RS/RK	.00000	.00027	1.000	-.0011	.0011	
				RS/ISD	.00099	.00027	.071	-.0001	.0021	
				RS	.00135 [*]	.00027	.004	.0007	.0020	
				Control/RP	.00807 [*]	.00027	.000	.0074	.0088	
RS	RS/RK			.00807 [*]	.00027	.000	.0074	.0088		
	Control/RP			.00807 [*]	.00027	.000	.0074	.0088		
	Control			-.00135 [*]	.00027	.004	-.0020	-.0007		
	RS/RK			.00672 [*]	.00027	.000	.0060	.0074		
RS/RK	RS/ISD			.00771 [*]	.00027	.000	.0070	.0084		
	Control/RP			.00672 [*]	.00027	.000	.0060	.0074		
	Control			-.00807 [*]	.00027	.000	-.0088	-.0074		
	RS			-.00672 [*]	.00027	.000	-.0074	-.0060		
RS/ISD	RS/ISD			.00099 [*]	.00027	.015	.0003	.0017		
	Control/RP			.00000	.00027	.994	-.0007	.0007		
	Control			-.00905 [*]	.00027	.000	-.0097	-.0084		
	RS			-.00771 [*]	.00027	.000	-.0084	-.0070		
Control/RP	RS/RK			-.00099 [*]	.00027	.015	-.0017	-.0003		
	Control/RP			-.00099 [*]	.00027	.015	-.0017	-.0003		
	Control			-.00807 [*]	.00027	.000	-.0088	-.0074		
	RS			-.00672 [*]	.00027	.000	-.0074	-.0060		
		RS/RK	.00000	.00027	.994	-.0007	.0007			
		RS/ISD	.00099 [*]	.00027	.015	.0003	.0017			
		RS	.00135 [*]	.00027	.004	.0007	.0020			
		Control/RP	.00807 [*]	.00027	.000	.0074	.0088			

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval				
						Lower Bound	Upper Bound			
Nystose_BD_BP	Tukey HSD	Control	RS	-.02684 [*]	.00157	.000	-.0331	-.0205		
			RS/RK	-.00643 [†]	.00157	.046	-.0127	-.0001		
			RS/ISD	-.01565 [*]	.00157	.001	-.0219	-.0094		
			Control/RP	.01604 [*]	.00157	.001	.0098	.0223		
		RS	Control	.02684 [*]	.00157	.000	.0205	.0331		
			RS/RK	.02040 [*]	.00157	.000	.0141	.0267		
			RS/ISD	.01119 [*]	.00157	.004	.0049	.0175		
			Control/RP	.04288 [*]	.00157	.000	.0366	.0492		
		RS/RK	Control	.00643 [†]	.00157	.046	.0001	.0127		
			RS	-.02040 [*]	.00157	.000	-.0267	-.0141		
			RS/ISD	-.00921 [†]	.00157	.011	-.0155	-.0029		
			Control/RP	.02248 [*]	.00157	.000	.0162	.0288		
		RS/ISD	Control	.01565 [*]	.00157	.001	.0094	.0219		
			RS	-.01119 [*]	.00157	.004	-.0175	-.0049		
			RS/RK	.00921 [†]	.00157	.011	.0029	.0155		
			Control/RP	.03169 [*]	.00157	.000	.0254	.0380		
		Control/RP	Control	-.01604 [*]	.00157	.001	-.0223	-.0098		
			RS	-.04288 [*]	.00157	.000	-.0492	-.0366		
			RS/RK	-.02248 [*]	.00157	.000	-.0288	-.0162		
			RS/ISD	-.03169 [*]	.00157	.000	-.0380	-.0254		
		LSD	Control	RS	-.02684 [*]	.00157	.000	-.0309	-.0228	
				RS/RK	-.00643 [†]	.00157	.009	-.0105	-.0024	
				RS/ISD	-.01565 [*]	.00157	.000	-.0197	-.0116	
				Control/RP	.01604 [*]	.00157	.000	.0120	.0201	
	RS		Control	.02684 [*]	.00157	.000	.0228	.0309		
			RS/RK	.02040 [*]	.00157	.000	.0164	.0244		
			RS/ISD	.01119 [*]	.00157	.001	.0072	.0152		
			Control/RP	.04288 [*]	.00157	.000	.0388	.0469		
	RS/RK		Control	.00643 [†]	.00157	.009	.0024	.0105		
			RS	-.02040 [*]	.00157	.000	-.0244	-.0164		
			RS/ISD	-.00921 [†]	.00157	.002	-.0132	-.0052		
			Control/RP	.02248 [*]	.00157	.000	.0184	.0265		
	RS/ISD		Control	.01565 [*]	.00157	.000	.0116	.0197		
			RS	-.01119 [*]	.00157	.001	-.0152	-.0072		
			RS/RK	.00921 [†]	.00157	.002	.0052	.0132		
			Control/RP	.03169 [*]	.00157	.000	.0277	.0357		
	Control/RP		Control	-.01604 [*]	.00157	.000	-.0201	-.0120		
			RS	-.04288 [*]	.00157	.000	-.0469	-.0388		
			RS/RK	-.02248 [*]	.00157	.000	-.0265	-.0184		
			RS/ISD	-.03169 [*]	.00157	.000	-.0357	-.0277		
	Nystose_BD_AP		Tukey HSD	Control	RS	-.04019 [*]	.00057	.000	-.0425	-.0379
					RS/RK	-.01505 [*]	.00057	.000	-.0173	-.0128
					RS/ISD	-.00795 [*]	.00057	.000	-.0102	-.0057
					Control/RP	.01256 [*]	.00057	.000	.0103	.0148
		RS		Control	.04019 [*]	.00057	.000	.0379	.0425	
				RS/RK	.02514 [*]	.00057	.000	.0229	.0274	
				RS/ISD	.03224 [*]	.00057	.000	.0300	.0345	
				Control/RP	.05275 [*]	.00057	.000	.0505	.0550	
RS/RK		Control		.01505 [*]	.00057	.000	.0128	.0173		
		RS		-.02514 [*]	.00057	.000	-.0274	-.0229		
		RS/ISD		.00710 [*]	.00057	.000	.0048	.0094		
		Control/RP		.02761 [*]	.00057	.000	.0253	.0299		
RS/ISD		Control		.00795 [*]	.00057	.000	.0057	.0102		
		RS		-.03224 [*]	.00057	.000	-.0345	-.0300		
		RS/RK		-.00710 [*]	.00057	.000	-.0094	-.0048		
		Control/RP		.02051 [*]	.00057	.000	.0182	.0228		
Control/RP		Control		-.01256 [*]	.00057	.000	-.0148	-.0103		
		RS		-.05275 [*]	.00057	.000	-.0550	-.0505		
		RS/RK		-.02761 [*]	.00057	.000	-.0299	-.0253		
		RS/ISD		-.02051 [*]	.00057	.000	-.0228	-.0182		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval			
						Lower Bound	Upper Bound		
LSD	Control	RS	-.04019 [*]	.00057	.000	-.0417	-.0387		
		RS/RK	-.01505 [*]	.00057	.000	-.0165	-.0136		
		RS/ISD	-.00795 [*]	.00057	.000	-.0094	-.0065		
		Control/RP	.01256 [*]	.00057	.000	.0111	.0140		
	RS	Control	.04019 [*]	.00057	.000	.0387	.0417		
		RS/RK	.02514 [*]	.00057	.000	.0237	.0266		
		RS/ISD	.03224 [*]	.00057	.000	.0308	.0337		
		Control/RP	.05275 [*]	.00057	.000	.0513	.0542		
	RS/RK	Control	.01505 [*]	.00057	.000	.0136	.0165		
		RS	-.02514 [*]	.00057	.000	-.0266	-.0237		
		RS/ISD	.00710 [*]	.00057	.000	.0056	.0086		
		Control/RP	.02761 [*]	.00057	.000	.0261	.0291		
	RS/ISD	Control	.00795 [*]	.00057	.000	.0065	.0094		
		RS	-.03224 [*]	.00057	.000	-.0337	-.0308		
		RS/RK	-.00710 [*]	.00057	.000	-.0086	-.0056		
		Control/RP	.02051 [*]	.00057	.000	.0190	.0220		
	Control/RP	Control	-.01256 [*]	.00057	.000	-.0140	-.0111		
		RS	-.05275 [*]	.00057	.000	-.0542	-.0513		
		RS/RK	-.02761 [*]	.00057	.000	-.0291	-.0261		
		RS/ISD	-.02051 [*]	.00057	.000	-.0220	-.0190		
	Totalfructan_BD_BP	Tukey HSD	Control	RS	.11481 [*]	.00340	.000	.1012	.1284
				RS/RK	.11380 [*]	.00340	.000	.1002	.1274
				RS/ISD	.07725 [*]	.00340	.000	.0636	.0909
				Control/RP	.00853	.00340	.226	-.0051	.0222
			RS	Control	-.11481	.00340	.000	-.1284	-.1012
				RS/RK	-.00101	.00340	.998	-.0146	.0126
				RS/ISD	-.03756 [*]	.00340	.001	-.0512	-.0239
				Control/RP	-.10628 [*]	.00340	.000	-.1199	-.0926
			RS/RK	Control	-.11380 [*]	.00340	.000	-.1274	-.1002
				RS	.00101	.00340	.998	-.0126	.0146
				RS/ISD	-.03655 [*]	.00340	.001	-.0502	-.0229
				Control/RP	-.10527 [*]	.00340	.000	-.1189	-.0916
			RS/ISD	Control	-.07725 [*]	.00340	.000	-.0909	-.0636
				RS	.03756 [*]	.00340	.001	.0239	.0512
				RS/RK	.03655 [*]	.00340	.001	.0229	.0502
				Control/RP	-.06872 [*]	.00340	.000	-.0824	-.0551
Control/RP			Control	-.00853	.00340	.226	-.0222	.0051	
			RS	.10628 [*]	.00340	.000	.0926	.1199	
			RS/RK	.10527 [*]	.00340	.000	.0916	.1189	
			RS/ISD	.06872 [*]	.00340	.000	.0551	.0824	
LSD			Control	RS	.11481 [*]	.00340	.000	.1061	.1235
				RS/RK	.11380 [*]	.00340	.000	.1051	.1225
				RS/ISD	.07725 [*]	.00340	.000	.0685	.0860
				Control/RP	.00853	.00340	.054	-.0002	.0173
			RS	Control	-.11481 [*]	.00340	.000	-.1235	-.1061
				RS/RK	-.00101	.00340	.779	-.0097	.0077
				RS/ISD	-.03756 [*]	.00340	.000	-.0463	-.0288
				Control/RP	-.10628 [*]	.00340	.000	-.1150	-.0975
			RS/RK	Control	-.11380 [*]	.00340	.000	-.1225	-.1051
				RS	.00101	.00340	.779	-.0077	.0097
				RS/ISD	-.03655 [*]	.00340	.000	-.0463	-.0278
				Control/RP	-.10527 [*]	.00340	.000	-.1140	-.0965
			RS/ISD	Control	-.07725 [*]	.00340	.000	-.0860	-.0685
				RS	.03756 [*]	.00340	.000	.0288	.0463
				RS/RK	.03655 [*]	.00340	.000	.0278	.0463
				Control/RP	-.06872 [*]	.00340	.000	-.0775	-.0600
	Control/RP	Control	-.00853	.00340	.054	-.0173	.0002		
		RS	.10628 [*]	.00340	.000	.0975	.1150		
		RS/RK	.10527 [*]	.00340	.000	.0965	.1140		
		RS/ISD	.06872 [*]	.00340	.000	.0600	.0775		

Multiple Comparisons

Dependent Variable	(I) Breaddough	(J) Breaddough	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval				
						Lower Bound	Upper Bound			
Totalfructan_BD_AP	Tukey HSD	Control	RS	.08754*	.00181	.000	.0803	.0948		
			RS/RK	.08156*	.00181	.000	.0743	.0888		
			RS/ISD	.05163*	.00181	.000	.0444	.0589		
			Control/RP	-.02158*	.00181	.000	-.0288	-.0143		
		RS	Control	-.08754*	.00181	.000	-.0948	-.0803		
			RS/RK	-.00598	.00181	.100	-.0132	.0013		
			RS/ISD	-.03591*	.00181	.000	-.0432	-.0286		
			Control/RP	-.10911*	.00181	.000	-.1164	-.1018		
		RS/RK	Control	-.08156*	.00181	.000	-.0888	-.0743		
			RS	.00598	.00181	.100	-.0013	.0132		
			RS/ISD	-.02993*	.00181	.000	-.0372	-.0227		
			Control/RP	-.10313*	.00181	.000	-.1104	-.0959		
		RS/ISD	Control	-.05163*	.00181	.000	-.0589	-.0444		
			RS	.03591*	.00181	.000	.0286	.0432		
			RS/RK	.02993*	.00181	.000	.0227	.0372		
			Control/RP	-.07321*	.00181	.000	-.0805	-.0659		
		Control/RP	Control	.02158*	.00181	.000	.0143	.0288		
			RS	.10911*	.00181	.000	.1018	.1164		
			RS/RK	.10313*	.00181	.000	.0959	.1104		
			RS/ISD	.07321*	.00181	.000	.0659	.0805		
		LSD	LSD	Control	RS	.08754*	.00181	.000	.0829	.0922
					RS/RK	.08156*	.00181	.000	.0769	.0862
					RS/ISD	.05163*	.00181	.000	.0470	.0563
					Control/RP	-.02158*	.00181	.000	-.0262	-.0169
				RS	Control	-.08754*	.00181	.000	-.0922	-.0829
					RS/RK	-.00598*	.00181	.022	-.0106	-.0013
					RS/ISD	-.03591*	.00181	.000	-.0406	-.0312
					Control/RP	-.10911*	.00181	.000	-.1138	-.1045
				RS/RK	Control	-.08156*	.00181	.000	-.0862	-.0769
					RS	.00598*	.00181	.022	.0013	.0106
					RS/ISD	-.02993*	.00181	.000	-.0346	-.0253
					Control/RP	-.10313*	.00181	.000	-.1078	-.0985
				RS/ISD	Control	-.05163*	.00181	.000	-.0563	-.0470
					RS	.03591*	.00181	.000	.0312	.0406
					RS/RK	.02993*	.00181	.000	.0253	.0346
					Control/RP	-.07321*	.00181	.000	-.0779	-.0685
				Control/RP	Control	.02158*	.00181	.000	.0169	.0262
					RS	.10911*	.00181	.000	.1045	.1138
					RS/RK	.10313*	.00181	.000	.0985	.1078
					RS/ISD	.07321*	.00181	.000	.0685	.0779

*. The mean difference is significant at the 0.05 level.

Fructose_BD_BP

		Subset for alpha = 0.05			
Breaddough	N	1	2	3	4
Tukey HSD ^a	RS/ISD	2	.0545		
	RS/RK	2	.0548		
	RS	2		.0850	
	Control	2			.1705
	Control/RP	2			
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Fructose_BD_AP

		Subset for alpha = 0.05				
Breaddough	N	1	2	3	4	5
Tukey HSD ^a	RS/RK	2	.0392			
	RS/ISD	2		.0465		
	RS	2			.0648	
	Control	2				.1549
	Control/RP	2				
Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Glucose_BD_BP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	Control/RP	2	.1027	
	RS/ISD	2	.1037	
	RS/RK	2	.1046	
	RS	2		.1307
	Control	2		
Sig.		.878	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Glucose_BD_AP

		Subset for alpha = 0.05				
Breaddough	N	1	2	3	4	
Tukey HSD ^a	RS/ISD	2	.0931			
	RS/RK	2	.0978			
	Control/RP	2		.1037		
	Control	2			.1256	
	RS	2				.1335
	Sig.		.256	.134	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Excessfructose_BD_BP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS	2	.0000	
	RS/RK	2	.0000	
	RS/ISD	2	.0000	
	Control	2		.0226
	Control/RP	2		
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Excessfructose_BD_AP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS	2	.0000	
	RS/RK	2	.0000	
	RS/ISD	2	.0000	
	Control	2		.0293
	Control/RP	2		
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Sorbitol_BD_BP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS/ISD	2	.0024	
	Control/RP	2		.0032
	RS/RK	2		.0035
	RS	2		.0036
	Control	2		
Sig.		1.000	.061	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Sorbitol_BD_AP

		Subset for alpha = 0.05				
Breaddough	N	1	2	3	4	
Tukey HSD ^a	RS/ISD	2	.0023			
	RS/RK	2		.0030		
	Control/RP	2		.0032		
	RS	2			.0035	
	Control	2				.0042
	Sig.		1.000	.241	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Mannitol_BD_BP

		Subset for alpha = 0.05			
Breaddough	N	1	2	3	
Tukey HSD ^a	RS	2	.0245		
	RS/RK	2	.0249		
	RS/ISD	2		.0284	
	Control/RP	2			.0324
	Control	2			.0333
	Sig.		.811	1.000	.134

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Mannitol_BD_AP

		Subset for alpha = 0.05			
Breaddough	N	1	2	3	
Tukey HSD ^a	RS	2	.0254		
	RS/RK	2	.0256		
	RS/ISD	2		.0293	
	Control	2			.0331
	Control/RP	2			.0338
	Sig.		.962	1.000	.331

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Raffinose_BD_BP

		Subset for alpha = 0.05			
Breaddough	N	1	2	3	
Tukey HSD ^a	RS	2	.0000		
	RS/RK	2	.0000		
	RS/ISD	2	.0000		
	Control/RP	2		.0009	
	Control	2			.0017
	Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Raffinose_BD_AP

		Subset for alpha = 0.05	
Breaddough	N	1	2
Tukey HSD ^a	RS	2	.0000
	RS/RK	2	.0000
	RS/ISD	2	.0000
	Control/RP	2	.0000
	Control	2	
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Stachyose_BD_BP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS/RK	2	.0039	
	RS/ISD	2	.0049	
	Control/RP	2	.0055	
	RS	2		.0096
	Control	2		.0119
	Sig.		.052	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Totalfructan_BD_BP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS	2	.0622	
	RS/RK	2	.0632	
	RS/ISD	2		.0997
	Control/RP	2		.1685
	Control	2		.1770
	Sig.		.998	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Stachyose_BD_AP

		Subset for alpha = 0.05		
Breaddough	N	1	2	3
Tukey HSD ^a	RS/ISD	2	.0044	
	Control/RP	2	.0054	
	RS/RK	2	.0054	
	RS	2		.0121
	Control	2		.0134
	Sig.		.071	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Totalfructan_BD_AP

		Subset for alpha = 0.05			
Breaddough	N	1	2	3	4
Tukey HSD ^a	RS	2	.0561		
	RS/RK	2	.0621		
	RS/ISD	2		.0920	
	Control	2			.1436
	Control/RP	2			.1852
	Sig.		.100	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Hystose_BD_BP

		Subset for alpha = 0.05					
Breaddough	N	1	2	3	4	5	
Tukey HSD ^a	Control/RP	2	.0228				
	Control	2		.0389			
	RS/RK	2			.0453		
	RS/ISD	2				.0545	
	RS	2				.0657	
	Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Hystose_BD_AP

		Subset for alpha = 0.05				
Breaddough	N	1	2	3	4	5
Tukey HSD ^a	Control/RP	2	.0236			
	Control	2		.0361		
	RS/ISD	2			.0441	
	RS/RK	2				.0512
	RS	2				.0763
	Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Fructose_Bread	Control	2	.2054	.00001	.00000	.2054	.2054	.21	.21
	RS	2	.1107	.00077	.00054	.1038	.1176	.11	.11
	RS/RK	2	.0822	.00266	.00188	.0583	.1061	.08	.08
	RS/ISD	2	.0890	.00233	.00164	.0681	.1099	.09	.09
	Control/RP	2	.1792	.00312	.00221	.1511	.2073	.18	.18
	Total	10	.1333	.05250	.01660	.0958	.1709	.08	.21
Glucose_Bread	Control	2	.1783	.00425	.00301	.1381	.2145	.17	.18
	RS	2	.1598	.00102	.00072	.1507	.1690	.16	.16
	RS/RK	2	.1531	.00871	.00616	.0749	.2314	.15	.16
	RS/ISD	2	.1353	.00060	.00042	.1299	.1407	.13	.14
	Control/RP	2	.1578	.00026	.00018	.1554	.1601	.16	.16
	Total	10	.1565	.01422	.00460	.1463	.1666	.13	.18
Excessfructose_Bread	Control	2	.0291	.00426	.00301	-.0091	.0674	.03	.03
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0214	.00338	.00239	-.0090	.0518	.02	.02
	Total	10	.0101	.01343	.00425	.0005	.0197	.00	.03
Sorbitol_Bread	Control	2	.0054	.00006	.00004	.0049	.0060	.01	.01
	RS	2	.0053	.00003	.00002	.0050	.0055	.01	.01
	RS/RK	2	.0056	.00000	.00000	.0056	.0056	.01	.01
	RS/ISD	2	.0053	.00001	.00000	.0052	.0053	.01	.01
	Control/RP	2	.0052	.00014	.00010	.0039	.0064	.01	.01
	Total	10	.0053	.00017	.00005	.0052	.0055	.01	.01
Mannitol_Bread	Control	2	.0397	.00007	.00005	.0390	.0403	.04	.04
	RS	2	.0302	.00003	.00002	.0299	.0305	.03	.03
	RS/RK	2	.0296	.00004	.00003	.0292	.0299	.03	.03
	RS/ISD	2	.0318	.00067	.00047	.0259	.0378	.03	.03
	Control/RP	2	.0396	.00139	.00098	.0271	.0520	.04	.04
	Total	10	.0342	.00479	.00151	.0307	.0376	.03	.04

Descriptives

		N	Mean	Std. Deviation	Std. Error	95 % Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Raffinose_Bread	Control	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Stachyose_Bread	Control	2	.0124	.00058	.00041	.0072	.0176	.01	.01
	RS	2	.0097	.00007	.00005	.0091	.0104	.01	.01
	RS/RK	2	.0056	.00015	.00011	.0042	.0069	.01	.01
	RS/ISD	2	.0066	.00015	.00010	.0053	.0079	.01	.01
	Control/RP	2	.0096	.00014	.00010	.0083	.0109	.01	.01
	Total	10	.0088	.00258	.00082	.0069	.0106	.01	.01
Kestose_Bread	Control	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/RK	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	RS/ISD	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Control/RP	2	.0000	.00000	.00000	.0000	.0000	.00	.00
	Total	10	.0000	.00000	.00000	.0000	.0000	.00	.00
Nystose_Bread	Control	2	.0464	.00207	.00146	.0278	.0650	.04	.05
	RS	2	.0617	.00043	.00031	.0578	.0656	.06	.06
	RS/RK	2	.0529	.00001	.00001	.0528	.0530	.05	.05
	RS/ISD	2	.0553	.00032	.00023	.0524	.0581	.06	.06
	Control/RP	2	.0440	.00074	.00052	.0374	.0506	.04	.04
	Total	10	.0521	.00673	.00213	.0473	.0569	.04	.06
Totalfructan_Bread	Control	2	.1310	.00331	.00234	.1013	.1607	.13	.13
	RS	2	.0657	.00614	.00434	.0105	.1209	.06	.07
	RS/RK	2	.0687	.00327	.00231	.0394	.0981	.07	.07
	RS/ISD	2	.0779	.00000	.00000	.0779	.0779	.08	.08
	Control/RP	2	.1010	.00317	.00224	.0725	.1295	.10	.10
	Total	10	.0889	.02590	.00819	.0704	.1074	.06	.13

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Fructose_Bread	Between Groups	.025	4	.006	1354.818	.000
	Within Groups	.000	5	.000		
	Total	.025	9			
Glucose_Bread	Between Groups	.002	4	.000	22.608	.002
	Within Groups	.000	5	.000		
	Total	.002	9			
Excessfructose_Bread	Between Groups	.002	4	.000	67.368	.000
	Within Groups	.000	5	.000		
	Total	.002	9			
Sorbitol_Bread	Between Groups	.000	4	.000	11.673	.009
	Within Groups	.000	5	.000		
	Total	.000	9			
Mannitol_Bread	Between Groups	.000	4	.000	107.394	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Raffinose_Bread	Between Groups	.000	4	.000		
	Within Groups	.000	5	.000		
	Total	.000	9			
Stachyose_Bread	Between Groups	.000	4	.000	181.058	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Kestose_Bread	Between Groups	.000	4	.000		
	Within Groups	.000	5	.000		
	Total	.000	9			
Nystose_Bread	Between Groups	.000	4	.000	98.397	.000
	Within Groups	.000	5	.000		
	Total	.000	9			
Totalfructan_Bread	Between Groups	.006	4	.001	107.474	.000
	Within Groups	.000	5	.000		
	Total	.006	9			

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
Fructose_Bread	Tukey HSD	Control	RS	.09470*	.00214	.000	.0861	.1033		
			RS/RK	.12318*	.00214	.000	.1146	.1318		
			RS/ISD	.11641*	.00214	.000	.1078	.1250		
			Control/RP	.02619*	.00214	.000	.0176	.0348		
		RS	Control	-.09470*	.00214	.000	-.1033	-.0861		
			RS/RK	.02848*	.00214	.000	.0199	.0371		
			RS/ISD	.02171*	.00214	.001	.0131	.0303		
			Control/RP	-.06851*	.00214	.000	-.0771	-.0599		
		RS/RK	Control	-.12318*	.00214	.000	-.1318	-.1146		
			RS	-.02848*	.00214	.000	-.0371	-.0199		
			RS/ISD	-.00677	.00214	.114	-.0153	.0018		
			Control/RP	-.09699*	.00214	.000	-.1056	-.0884		
		RS/ISD	Control	-.11641*	.00214	.000	-.1250	-.1078		
			RS	-.02171*	.00214	.001	-.0303	-.0131		
			RS/RK	.00677	.00214	.114	-.0018	.0153		
			Control/RP	-.09022*	.00214	.000	-.0988	-.0816		
		Control/RP	Control	-.02619*	.00214	.000	-.0348	-.0176		
			RS	.06851*	.00214	.000	.0599	.0771		
			RS/RK	.09699*	.00214	.000	.0884	.1056		
			RS/ISD	.09022*	.00214	.000	.0816	.0988		
		LSD	Control	RS	.09470*	.00214	.000	.0892	.1002	
				RS/RK	.12318*	.00214	.000	.1177	.1287	
				RS/ISD	.11641*	.00214	.000	.1109	.1219	
				Control/RP	.02619*	.00214	.000	.0207	.0317	
	RS		Control	-.09470*	.00214	.000	-.1002	-.0892		
			RS/RK	.02848*	.00214	.000	.0230	.0340		
			RS/ISD	.02171*	.00214	.000	.0162	.0272		
			Control/RP	-.06851*	.00214	.000	-.0740	-.0630		
	RS/RK		Control	-.12318*	.00214	.000	-.1287	-.1177		
			RS	-.02848*	.00214	.000	-.0340	-.0230		
			RS/ISD	-.00677*	.00214	.025	-.0123	-.0013		
			Control/RP	-.09699*	.00214	.000	-.1025	-.0915		
	RS/ISD		Control	-.11641*	.00214	.000	-.1219	-.1109		
			RS	-.02171*	.00214	.000	-.0272	-.0162		
			RS/RK	.00677*	.00214	.025	.0013	.0123		
			Control/RP	-.09022*	.00214	.000	-.0957	-.0847		
	Control/RP		Control	-.02619*	.00214	.000	-.0317	-.0207		
			RS	.06851*	.00214	.000	.0630	.0740		
			RS/RK	.09699*	.00214	.000	.0915	.1025		
			RS/ISD	.09022*	.00214	.000	.0847	.0957		
	Glucose_Bread		Tukey HSD	Control	RS	.01643	.00437	.063	-.0011	.0340
					RS/RK	.02311*	.00437	.017	.0056	.0406
					RS/ISD	.04093*	.00437	.001	.0234	.0584
					Control/RP	.01847*	.00437	.041	.0010	.0360
		RS		Control	-.01643	.00437	.063	-.0340	.0011	
				RS/RK	-.00668	.00437	.587	-.0108	.0242	
				RS/ISD	.02450*	.00437	.013	.0070	.0420	
				Control/RP	.00204	.00437	.987	-.0155	.0196	
RS/RK		Control		-.02311*	.00437	.017	-.0406	-.0056		
		RS		-.00668	.00437	.587	-.0242	.0108		
		RS/ISD		.01781*	.00437	.047	.0003	.0353		
		Control/RP		-.00464	.00437	.818	-.0222	.0129		
RS/ISD		Control		-.04093*	.00437	.001	-.0584	-.0234		
		RS		-.02450*	.00437	.013	-.0420	-.0070		
		RS/RK		-.01781*	.00437	.047	-.0353	-.0003		
		Control/RP		-.02246*	.00437	.019	-.0400	-.0049		
Control/RP		Control		-.01847*	.00437	.041	-.0360	-.0010		
		RS		-.00204	.00437	.987	-.0196	.0155		
		RS/RK		.00464	.00437	.818	-.0129	.0222		
		RS/ISD		.02246*	.00437	.019	.0049	.0400		
LSD		Control		RS	.01643*	.00437	.013	.0052	.0277	
				RS/RK	.02311*	.00437	.003	.0119	.0343	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS	RS/ISD	.04093*	.00437	.000	.0297	.0522		
		Control/RP	.01847*	.00437	.008	.0072	.0297		
		Control	-.01643*	.00437	.013	-.0277	-.0052		
		RS/RK	.00668	.00437	.186	-.0045	.0179		
		RS/ISD	.02450*	.00437	.002	.0133	.0357		
		Control/RP	.00204	.00437	.660	-.0092	.0133		
		Control	-.02311*	.00437	.003	-.0343	-.0119		
		RS	-.00668	.00437	.186	-.0179	.0045		
		RS/ISD	.01781*	.00437	.010	.0066	.0290		
		Control/RP	-.00464	.00437	.336	-.0159	.0066		
		Control	-.04093*	.00437	.000	-.0522	-.0297		
		RS	-.02450*	.00437	.002	-.0357	-.0133		
	RS/RK	-.01781*	.00437	.010	-.0290	-.0066			
	Control/RP	-.02246*	.00437	.004	-.0337	-.0112			
	Control/RP	Control	-.01847*	.00437	.008	-.0297	-.0072		
	RS	-.00204	.00437	.660	-.0133	.0092			
	RS/RK	.00464	.00437	.336	-.0066	.0159			
	RS/ISD	.02246*	.00437	.004	.0112	.0337			
	Excessfructose_bread	Tukey HSD	Control	RS	.02915*	.00243	.000	.0194	.0389
			RS/RK	.02915*	.00243	.000	.0194	.0389	
			RS/ISD	.02915*	.00243	.000	.0194	.0389	
			Control/RP	.00772	.00243	.113	-.0020	.0175	
			RS	Control	-.02915*	.00243	.000	-.0389	-.0194
			RS/RK	.00000	.00243	1.000	-.0098	.0098	
			RS/ISD	.00000	.00243	1.000	-.0098	.0098	
			Control/RP	-.02143*	.00243	.002	-.0312	-.0117	
			RS/RK	Control	-.02915*	.00243	.000	-.0389	-.0194
			RS	.00000	.00243	1.000	-.0098	.0098	
			RS/ISD	.00000	.00243	1.000	-.0098	.0098	
			Control/RP	-.02143*	.00243	.002	-.0312	-.0117	
		RS/ISD	Control	-.02915*	.00243	.000	-.0389	-.0194	
		RS	.00000	.00243	1.000	-.0098	.0098		
		RS/RK	.00000	.00243	1.000	-.0098	.0098		
Control/RP		-.02143*	.00243	.002	-.0312	-.0117			
Control/RP		Control	-.00772	.00243	.113	-.0175	.0020		
RS		.02143*	.00243	.002	.0117	.0312			
RS/RK		.02143*	.00243	.002	.0117	.0312			
RS/ISD		.02143*	.00243	.002	.0117	.0312			
LSD		Control	RS	.02915*	.00243	.000	.0229	.0354	
			RS/RK	.02915*	.00243	.000	.0229	.0354	
			RS/ISD	.02915*	.00243	.000	.0229	.0354	
			Control/RP	.00772*	.00243	.025	.0015	.0140	
			RS	Control	-.02915*	.00243	.000	-.0354	-.0229
			RS/RK	.00000	.00243	1.000	-.0063	.0063	
			RS/ISD	.00000	.00243	1.000	-.0063	.0063	
			Control/RP	-.02143*	.00243	.000	-.0277	-.0152	
			RS/RK	Control	-.02915*	.00243	.000	-.0354	-.0229
			RS	.00000	.00243	1.000	-.0063	.0063	
			RS/ISD	.00000	.00243	1.000	-.0063	.0063	
			Control/RP	-.02143*	.00243	.000	-.0277	-.0152	
		RS/ISD	Control	-.02915*	.00243	.000	-.0354	-.0229	
	RS	.00000	.00243	1.000	-.0063	.0063			
	RS/RK	.00000	.00243	1.000	-.0063	.0063			
	Control/RP	-.02143*	.00243	.000	-.0277	-.0152			
	Control/RP	Control	-.00772*	.00243	.025	-.0140	-.0015		
	RS	.02143*	.00243	.000	.0152	.0277			
	RS/RK	.02143*	.00243	.000	.0152	.0277			
	RS/ISD	.02143*	.00243	.000	.0152	.0277			
	Tukey HSD	Control	RS	.00015	.00007	.319	-.0001	.0004	
			RS/RK	-.00020	.00007	.156	-.0005	.0001	
			RS/ISD	.00014	.00007	.391	-.0001	.0004	
			Control/RP	.00023	.00007	.103	-.0001	.0005	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
LSD	RS	Control	-.00015	.00007	.319	-.0004	.0001		
		RS/RK	-.00035*	.00007	.020	-.0006	-.0001		
		RS/ISD	-.00001	.00007	.999	-.0003	.0003		
		Control/RP	.00008	.00007	.805	-.0002	.0004		
	RS/RK	Control	.00020	.00007	.156	-.0001	.0005		
		RS	.00035*	.00007	.020	.0001	.0006		
		RS/ISD	.00034*	.00007	.024	.0001	.0006		
		Control/RP	.00043*	.00007	.009	.0001	.0007		
	RS/ISD	Control	-.00014	.00007	.391	-.0004	.0001		
		RS	.00001	.00007	.999	-.0003	.0003		
		RS/RK	-.00034*	.00007	.024	-.0006	-.0001		
		Control/RP	-.00009	.00007	.707	-.0002	.0004		
	Control/RP	Control	-.00023	.00007	.103	-.0005	.0001		
		RS	-.00008	.00007	.805	-.0004	.0002		
		RS/RK	-.00043*	.00007	.009	-.0007	-.0001		
		RS/ISD	-.00009	.00007	.707	-.0004	.0002		
	Mannitol_Bread	Tukey HSD	Control	RS	.00947*	.00069	.000	.0067	.0122
				RS/RK	.01011*	.00069	.000	.0074	.0129
				RS/ISD	.00783*	.00069	.001	.0051	.0106
				Control/RP	.00010	.00069	1.000	-.0027	.0029
			RS	Control	-.00947*	.00069	.000	-.0122	-.0067
				RS/RK	-.00064	.00069	.872	-.0021	.0034
				RS/ISD	-.00164	.00069	.259	-.0044	.0011
				Control/RP	-.00937*	.00069	.000	-.0121	-.0066
			RS/RK	Control	-.01011*	.00069	.000	-.0129	-.0074
				RS	-.00064	.00069	.872	-.0034	.0021
				RS/ISD	-.00228	.00069	.099	-.0050	.0005
				Control/RP	-.01001*	.00069	.000	-.0128	-.0072
		RS/ISD	Control	-.00783*	.00069	.001	-.0106	-.0051	
			RS	.00164	.00069	.259	-.0011	.0044	
			RS/RK	.00228	.00069	.099	-.0005	.0005	
			Control/RP	-.00773*	.00069	.001	-.0105	-.0050	
		Control/RP	Control	-.00010	.00069	1.000	-.0029	.0027	
			RS	.00937*	.00069	.000	.0066	.0121	
			RS/RK	.01001*	.00069	.000	.0072	.0128	
			RS/ISD	.00773*	.00069	.001	.0050	.0105	
LSD		Control	RS	.00947*	.00069	.000	.0077	.0112	
			RS/RK	.01011*	.00069	.000	.0083	.0119	
			RS/ISD	.00783*	.00069	.000	.0061	.0096	
			Control/RP	.00010	.00069	.889	-.0017	.0019	
		RS	Control	-.00947*	.00069	.000	-.0112	-.0077	
			RS/RK	-.00064	.00069	.392	-.0011	.0024	
			RS/ISD	-.00164	.00069	.063	-.0034	.0001	
			Control/RP	-.00937*	.00069	.000	-.0111	-.0076	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
	RS/RK	Control	-.01011*	.00069	.000	-.0119	-.0083	
		RS	-.00064	.00069	.392	-.0024	.0011	
		RS/ISD	-.00228*	.00069	.021	-.0041	-.0005	
	RS/ISD	Control/RP	-.01001*	.00069	.000	-.0118	-.0082	
		Control	-.00783*	.00069	.000	-.0096	-.0061	
		RS	.00164	.00069	.063	-.0001	.0034	
		RS/RK	.00228*	.00069	.021	.0005	.0041	
	Control/RP	Control/RP	-.00773*	.00069	.000	-.0095	-.0060	
		Control	-.00010	.00069	.889	-.0019	.0017	
		RS	.00937*	.00069	.000	.0076	.0111	
		RS/RK	.01001*	.00069	.000	.0082	.0118	
		RS/ISD	.00773*	.00069	.000	.0060	.0095	
		Control	.00267*	.00029	.001	.0015	.0038	
		RS/RK	.00681*	.00029	.000	.0057	.0080	
	Stachyose_Bread	Tukey HSD	Control	RS/ISD	.00581*	.00029	.000	.0047
Control/RP				.00278*	.00029	.001	.0016	.0039
RS				-.00267*	.00029	.001	-.0038	-.0015
RS/RK				.00415*	.00029	.000	.0030	.0053
RS/ISD				.00314*	.00029	.001	.0020	.0043
RS		Control/RP	.00011	.00029	.993	-.0010	.0013	
		Control	-.00681*	.00029	.000	-.0080	-.0057	
		RS	-.00415*	.00029	.000	-.0053	-.0030	
		RS/ISD	-.00100	.00029	.081	-.0022	.0001	
RS/RK		Control/RP	-.00403*	.00029	.000	-.0052	-.0029	
		Control	-.00581*	.00029	.000	-.0070	-.0047	
		RS	-.00314*	.00029	.001	-.0043	-.0020	
RS/ISD		RS/RK	.00100	.00029	.081	-.0001	.0022	
		Control/RP	-.00303*	.00029	.001	-.0042	-.0019	
		Control	-.00278*	.00029	.001	-.0039	-.0016	
	RS	-.00011	.00029	.993	-.0013	.0010		
LSD	Control	RS/RK	.00403*	.00029	.000	.0029	.0052	
		RS/ISD	.00303*	.00029	.001	.0019	.0042	
		Control	.00267*	.00029	.000	.0019	.0034	
		RS/RK	.00681*	.00029	.000	.0061	.0076	
		RS/ISD	.00581*	.00029	.000	.0051	.0065	
	RS	Control/RP	.00278*	.00029	.000	.0020	.0035	
		Control	-.00267*	.00029	.000	-.0034	-.0019	
		RS/RK	.00415*	.00029	.000	.0034	.0049	
		RS/ISD	.00314*	.00029	.000	.0024	.0039	
		Control/RP	.00011	.00029	.708	-.0006	.0008	
RS/RK	Control	-.00681*	.00029	.000	-.0076	-.0061		
	RS	-.00415*	.00029	.000	-.0049	-.0034		
	RS/ISD	-.00100*	.00029	.017	-.0017	-.0003		
	Control/RP	-.00403*	.00029	.000	-.0048	-.0033		
RS/ISD	Control	-.00581*	.00029	.000	-.0065	-.0051		
	RS	-.00314*	.00029	.000	-.0039	-.0024		
	RS/RK	.00100*	.00029	.017	.0003	.0017		
	Control/RP	-.00303*	.00029	.000	-.0038	-.0023		
Control/RP	Control	-.00278*	.00029	.000	-.0035	-.0020		
	RS	-.00011	.00029	.708	-.0008	.0006		
	RS/RK	.00403*	.00029	.000	.0033	.0048		
	RS/ISD	.00303*	.00029	.000	.0023	.0038		
	Control	.00267*	.00101	.000	.00194	.0034		
Nystose_Bread	Tukey HSD	Control	RS/RK	-.00649*	.00101	.007	-.0105	-.0024
			RS/ISD	-.00884*	.00101	.002	-.0129	-.0048
			Control/RP	.00241	.00101	.257	-.0016	.0065
			Control	.01531*	.00101	.000	.0113	.0194
			RS	.00882*	.00101	.002	.0048	.0129
	RS	RS/ISD	.00647*	.00101	.007	.0024	.0105	
		Control/RP	.01772*	.00101	.000	.0137	.0218	
		Control	.00649*	.00101	.007	.0024	.0105	
		RS	-.00882*	.00101	.002	-.0129	-.0048	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	LSD	RS/ISD	RS	-.00235	.00101	.273	-.0064	.0017	
			Control/RS	.00890*	.00101	.002	.0048	.0130	
		RS/RS	Control	.00884*	.00101	.002	.0048	.0129	
			RS	-.00647*	.00101	.007	-.0105	-.0024	
		RS/RK	RS	.00235	.00101	.273	-.0017	.0064	
			Control/RS	.01125*	.00101	.001	.0072	.0153	
		Control/RS	Control	-.00241	.00101	.257	-.0065	.0016	
			RS	-.01772*	.00101	.000	-.0218	-.0137	
			RS/RK	-.00890*	.00101	.002	-.0130	-.0048	
			RS/ISD	-.01125*	.00101	.001	-.0153	-.0072	
		LSD	Control	RS	-.01531*	.00101	.000	-.0179	-.0127
				RS/RK	-.00649*	.00101	.001	-.0091	-.0039
	RS/ISD		Control	-.00884*	.00101	.000	-.0114	-.0062	
			Control/RS	.00241	.00101	.063	-.0002	.0050	
	RS		Control	.01531*	.00101	.000	.0127	.0179	
			RS/RK	.00882*	.00101	.000	.0062	.0114	
			RS/ISD	.00647*	.00101	.001	.0039	.0091	
			Control/RS	.01772*	.00101	.000	.0151	.0203	
	RS/RK		Control	.00649*	.00101	.001	.0039	.0091	
			RS	-.00882*	.00101	.000	-.0114	-.0062	
			RS/ISD	-.00235	.00101	.068	-.0049	.0002	
			Control/RS	.00890*	.00101	.000	.0063	.0115	
	RS/ISD	Control	.00884*	.00101	.000	.0062	.0114		
		RS	-.00647*	.00101	.001	-.0091	-.0039		
		RS/RK	.00235	.00101	.068	-.0002	.0049		
		Control/RS	.01125*	.00101	.000	.0087	.0139		
	Control/RS	Control	-.00241	.00101	.063	-.0050	.0002		
		RS	-.01772*	.00101	.000	-.0203	-.0151		
		RS/RK	-.00890*	.00101	.000	-.0115	-.0063		
		RS/ISD	-.01125*	.00101	.000	-.0139	-.0087		
	Totalfructan_Bread	Tukey HSD	Control	RS	.06530*	.00373	.000	.0504	.0802
				RS/RK	.06227*	.00373	.000	.0473	.0772
				RS/ISD	.05308*	.00373	.000	.0381	.0680
				Control/RS	.03002*	.00373	.003	.0151	.0450
			RS	Control	-.06530*	.00373	.000	-.0802	-.0504
				RS/RK	-.00303	.00373	.916	-.0180	.0119
				RS/ISD	-.01222	.00373	.102	-.0272	.0027
				Control/RS	-.03528*	.00373	.001	-.0502	-.0203
			RS/RK	Control	-.06227*	.00373	.000	-.0772	-.0473
				RS	.00303	.00373	.916	-.0119	.0180
				RS/ISD	-.00919	.00373	.236	-.0241	.0058
				Control/RS	-.03225*	.00373	.002	-.0472	-.0173
			RS/ISD	Control	-.05308*	.00373	.000	-.0680	-.0381
				RS	.01222	.00373	.102	-.0027	.0272
				RS/RK	.00919	.00373	.236	-.0058	.0241
				Control/RS	-.02306*	.00373	.008	-.0380	-.0081
			Control/RS	Control	-.03002*	.00373	.003	-.0450	-.0151
				RS	.03528*	.00373	.001	.0203	.0502
RS/RK				.03225*	.00373	.002	.0173	.0472	
RS/ISD				.02306*	.00373	.008	.0081	.0380	
LSD			Control	RS	.06530*	.00373	.000	.0557	.0749
				RS/RK	.06227*	.00373	.000	.0527	.0718
				RS/ISD	.05308*	.00373	.000	.0435	.0627
				Control/RS	.03002*	.00373	.000	.0204	.0396
		RS	Control	-.06530*	.00373	.000	-.0749	-.0557	
			RS/RK	-.00303	.00373	.453	-.0126	.0065	
			RS/ISD	-.01222*	.00373	.022	-.0218	-.0026	
			Control/RS	-.03528*	.00373	.000	-.0449	-.0257	
		RS/RK	Control	-.06227*	.00373	.000	-.0718	-.0527	
			RS	.00303	.00373	.453	-.0065	.0126	
			RS/ISD	-.00919	.00373	.057	-.0188	.0004	
			Control/RS	-.03225*	.00373	.000	-.0418	-.0227	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
	RS/ISD	Control	-.06308*	.00373	.000	-.0627	-.0435
		RS	.01222*	.00373	.022	.0026	.0218
		RS/RK	.00919	.00373	.057	-.0004	.0188
		Control/RP	-.02306*	.00373	.002	-.0326	-.0135
	Control/RP	Control	-.03002*	.00373	.000	-.0396	-.0204
		RS	.03528*	.00373	.000	.0257	.0449
		RS/RK	.03225*	.00373	.000	.0227	.0418
		RS/ISD	.02306*	.00373	.002	.0135	.0326

*. The mean difference is significant at the 0.05 level.

Fructose_Bread

Bread	N	Subset for alpha = 0.05				
		1	2	3	4	
Tukey HSD ^a	RS/RK	2	.0822			
	RS/ISD	2	.0890			
	RS	2		.1107		
	Control/RP	2			.1792	
	Control	2				.2054
Sig.			.114	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Mannitol_Bread

Bread	N	Subset for alpha = 0.05	
		1	2
Tukey HSD ^a	RS/RK	2	.0296
	RS	2	.0302
	RS/ISD	2	.0318
	Control/RP	2	.0396
	Control	2	.0397
Sig.			.099

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Glucose_Bread

Bread	N	Subset for alpha = 0.05		
		1	2	3
Tukey HSD ^a	RS/ISD	2	.1353	
	RS/RK	2		.1531
	Control/RP	2		.1578
	RS	2		.1598
	Control	2		.1763
Sig.			1.000	.587

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Stachyose_Bread

Bread	N	Subset for alpha = 0.05		
		1	2	3
Tukey HSD ^a	RS/RK	2	.0056	
	RS/ISD	2	.0066	
	Control/RP	2		.0096
	RS	2		.0097
	Control	2		.0124
Sig.			.081	.993

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Excessfructose_Bread

Bread	N	Subset for alpha = 0.05	
		1	2
Tukey HSD ^a	RS	2	.0000
	RS/RK	2	.0000
	RS/ISD	2	.0000
	Control/RP	2	.0214
	Control	2	.0291
Sig.			1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Inystose_Bread

Bread	N	Subset for alpha = 0.05		
		1	2	3
Tukey HSD ^a	Control/RP	2	.0440	
	Control	2	.0464	
	RS/RK	2		.0529
	RS/ISD	2		.0553
	RS	2		.0617
Sig.			.257	.273

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Sorbitol_Bread

Bread	N	Subset for alpha = 0.05	
		1	2
Tukey HSD ^a	Control/RP	2	.0052
	RS	2	.0053
	RS/ISD	2	.0053
	Control	2	.0054
	RS/RK	2	
Sig.			.103

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Totalfructan_Bread

Bread	N	Subset for alpha = 0.05		
		1	2	3
Tukey HSD ^a	RS	2	.0657	
	RS/RK	2	.0687	
	RS/ISD	2	.0779	
	Control/RP	2		.1010
	Control	2		.1310
Sig.			.102	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

D.9 Statistical analysis of loaf weight, loaf volume, specific volume and baking weight loss of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Loafweight_Bread	Control	3	534.6667	1.15470	.66667	531.7982	537.5351	534.00	536.00
	RS	3	538.6667	3.05505	1.76383	531.0775	546.2558	536.00	542.00
	RS/RK	3	525.6667	.57735	.33333	524.2324	527.1009	525.00	526.00
	RS/ISD	3	534.3333	2.08167	1.20185	529.1622	539.5045	532.00	536.00
	Control/RP	3	565.0000	1.73205	1.00000	560.6973	569.3027	563.00	566.00
	Total	15	539.6667	13.92155	3.59453	531.9572	547.3762	525.00	566.00
Loafvolume_Bread	Control	3	1236.6667	5.77350	3.33333	1222.3245	1251.0088	1230.00	1240.00
	RS	3	1313.3333	5.77350	3.33333	1298.9912	1327.6755	1310.00	1320.00
	RS/RK	3	1175.0000	5.00000	2.88675	1162.5793	1187.4207	1170.00	1180.00
	RS/ISD	3	1326.6667	5.77350	3.33333	1312.3245	1341.0088	1320.00	1330.00
	Control/RP	3	1241.6667	7.63763	4.40959	1222.6938	1260.6396	1235.00	1250.00
	Total	15	1258.6667	57.64629	14.88421	1226.7432	1290.5901	1170.00	1330.00
Specificivolume_Bread	Control	3	2.3130	.00937	.00541	2.2897	2.3362	2.30	2.32
	RS	3	2.4382	.02303	.01330	2.3810	2.4954	2.42	2.46
	RS/RK	3	2.2353	.01171	.00676	2.2062	2.2643	2.22	2.25
	RS/ISD	3	2.4828	.00272	.00157	2.4761	2.4896	2.48	2.49
	Control/RP	3	2.1976	.00950	.00548	2.1740	2.2212	2.19	2.21
	Total	15	2.3334	.11560	.02985	2.2694	2.3974	2.19	2.49
Bakingweightloss_Bread	Control	3	13.7634	.18624	.10753	13.3008	14.2261	13.55	13.87
	RS	3	13.1183	.49275	.28449	11.8942	14.3423	12.58	13.55
	RS/RK	3	15.2151	.09312	.05376	14.9837	15.4464	15.16	15.32
	RS/ISD	3	13.8172	.33575	.19385	12.9831	14.6513	13.55	14.19
	Control/RP	3	8.8710	.27936	.16129	8.1770	9.5649	8.71	9.19
	Total	15	12.9570	2.24541	.57976	11.7135	14.2005	8.71	15.32

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Loafweight_Bread	Between Groups	2676.667	4	669.167	182.500	.000
	Within Groups	36.667	10	3.667		
	Total	2713.333	14			
Loafvolume_Bread	Between Groups	46156.667	4	11539.167	314.705	.000
	Within Groups	366.667	10	36.667		
	Total	46523.333	14			
Specificivolume_Bread	Between Groups	.185	4	.046	271.721	.000
	Within Groups	.002	10	.000		
	Total	.187	14			
Bakingweightloss_Bread	Between Groups	69.632	4	17.408	182.500	.000
	Within Groups	.954	10	.095		
	Total	70.586	14			

Multiple Comparisons

Dependent Variable		(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Loafweight_Bread	Tukey HSD	Control	RS	-4.00000	1.56347	.153	-9.1455	1.1455
			RS/RK	9.00000*	1.56347	.001	3.8545	14.1455
			RS/ISD	.33333	1.56347	.999	-4.8122	5.4788
			Control/RP	-30.33333*	1.56347	.000	-35.4788	-25.1878
		RS	Control	4.00000	1.56347	.153	-1.1455	9.1455
			RS/RK	13.00000*	1.56347	.000	7.8545	18.1455
			RS/ISD	4.33333	1.56347	.111	-.8122	9.4788
			Control/RP	-26.33333*	1.56347	.000	-31.4788	-21.1878
		RS/RK	Control	-9.00000*	1.56347	.001	-14.1455	-3.8545
			RS	-13.00000*	1.56347	.000	-18.1455	-7.8545
			RS/ISD	-8.66667*	1.56347	.002	-13.8122	-3.5212
			Control/RP	-39.33333*	1.56347	.000	-44.4788	-34.1878
		RS/ISD	Control	-.33333	1.56347	.999	-5.4788	4.8122
			RS	-4.33333	1.56347	.111	-9.4788	.8122
			RS/RK	8.66667*	1.56347	.002	3.5212	13.8122
			Control/RP	-30.66667*	1.56347	.000	-35.8122	-25.5212
		Control/RP	Control	30.33333*	1.56347	.000	25.1878	35.4788
			RS	26.33333*	1.56347	.000	21.1878	31.4788
			RS/RK	39.33333*	1.56347	.000	34.1878	44.4788
			RS/ISD	30.66667*	1.56347	.000	25.5212	35.8122
	LSD	Control	RS	-4.00000*	1.56347	.028	-7.4836	-.5164
			RS/RK	9.00000*	1.56347	.000	5.5164	12.4836
			RS/ISD	.33333	1.56347	.935	-3.1503	3.8170
			Control/RP	-30.33333*	1.56347	.000	-33.8170	-26.8497
		RS	Control	4.00000*	1.56347	.028	.5164	7.4836
			RS/RK	13.00000*	1.56347	.000	9.5164	16.4836
			RS/ISD	4.33333*	1.56347	.020	.8497	7.8170
			Control/RP	-26.33333*	1.56347	.000	-29.8170	-22.8497
		RS/RK	Control	-9.00000*	1.56347	.000	-12.4836	-5.5164
			RS	-13.00000*	1.56347	.000	-16.4836	-9.5164
			RS/ISD	-8.66667*	1.56347	.000	-12.1503	-5.1830
			Control/RP	-39.33333*	1.56347	.000	-42.8170	-35.8497
		RS/ISD	Control	-.33333	1.56347	.835	-3.8170	3.1503
			RS	-4.33333*	1.56347	.020	-7.8170	-.8497
			RS/RK	8.66667*	1.56347	.000	5.1830	12.1503
			Control/RP	-30.66667*	1.56347	.000	-34.1503	-27.1830
		Control/RP	Control	30.33333*	1.56347	.000	26.8497	33.8170
			RS	26.33333*	1.56347	.000	22.8497	29.8170
			RS/RK	39.33333*	1.56347	.000	35.8497	42.8170
			RS/ISD	30.66667*	1.56347	.000	27.1830	34.1503
Loafvolume_Bread	Tukey HSD	Control	RS	-76.66667*	4.94413	.000	-92.9382	-60.3951
			RS/RK	61.66667*	4.94413	.000	45.3951	77.9382
			RS/ISD	-90.00000*	4.94413	.000	-106.2715	-73.7285
			Control/RP	-5.00000	4.94413	.845	-21.2715	11.2715
		RS	Control	76.66667*	4.94413	.000	60.3951	92.9382
			RS/RK	138.33333*	4.94413	.000	122.0618	154.6049
			RS/ISD	-13.33333	4.94413	.124	-29.6049	2.9382
			Control/RP	71.66667*	4.94413	.000	55.3951	87.9382
		RS/RK	Control	-61.66667*	4.94413	.000	-77.9382	-45.3951
			RS	-138.33333*	4.94413	.000	-154.6049	-122.0618
			RS/ISD	-151.66667*	4.94413	.000	-167.9382	-135.3951
			Control/RP	-66.66667*	4.94413	.000	-82.9382	-50.3951
		RS/ISD	Control	90.00000*	4.94413	.000	73.7285	106.2715
			RS	13.33333	4.94413	.124	-2.9382	29.6049

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
LSD	Control/RP	RS/RK	151.66667 [*]	4.94413	.000	135.3951	167.9382			
		Control/RP	85.00000 [*]	4.94413	.000	68.7285	101.2715			
	Control	Control	5.00000	4.94413	.845	-11.2715	21.2715			
		RS	-71.66667 [*]	4.94413	.000	-87.9382	-55.3951			
	RS/RK	RS/RK	66.66667 [*]	4.94413	.000	50.3951	82.9382			
		RS/ISD	-85.00000 [*]	4.94413	.000	-101.2715	-68.7285			
	Control	RS	-76.66667 [*]	4.94413	.000	-87.6829	-65.6505			
		RS/RK	61.66667 [*]	4.94413	.000	50.6505	72.6829			
		RS/ISD	-90.00000 [*]	4.94413	.000	-101.0162	-78.9838			
		Control/RP	-5.00000	4.94413	.336	-16.0162	6.0162			
	RS	Control	76.66667 [*]	4.94413	.000	65.6505	87.6829			
		RS/RK	138.33333 [*]	4.94413	.000	127.3171	149.3495			
		RS/ISD	-13.33333 [*]	4.94413	.022	-24.3495	-2.3171			
		Control/RP	71.66667 [*]	4.94413	.000	60.6505	82.6829			
	RS/RK	Control	-61.66667 [*]	4.94413	.000	-72.6829	-50.6505			
		RS	-138.33333 [*]	4.94413	.000	-149.3495	-127.3171			
		RS/ISD	-151.66667 [*]	4.94413	.000	-162.6829	-140.6505			
		Control/RP	-66.66667 [*]	4.94413	.000	-77.6829	-55.6505			
	RS/ISD	Control	90.00000 [*]	4.94413	.000	78.9838	101.0162			
		RS	13.33333 [*]	4.94413	.022	2.3171	24.3495			
		RS/RK	151.66667 [*]	4.94413	.000	140.6505	162.6829			
		Control/RP	85.00000 [*]	4.94413	.000	73.9838	96.0162			
	Control/RP	Control	5.00000	4.94413	.336	-6.0162	16.0162			
		RS	-71.66667 [*]	4.94413	.000	-82.6829	-60.6505			
		RS/RK	66.66667 [*]	4.94413	.000	55.6505	77.6829			
		RS/ISD	-85.00000 [*]	4.94413	.000	-96.0162	-73.9838			
	Specificivolume_Bread	Tukey HSD	Control	RS	-.12523 [*]	.01066	.000	-.1603	-.0901	
				RS/RK	.07770 [*]	.01066	.000	.0426	.1128	
				RS/ISD	-.16988 [*]	.01066	.000	-.2050	-.1348	
				Control/RP	.11533 [*]	.01066	.000	.0802	.1504	
			RS	Control	.12523 [*]	.01066	.000	.0901	.1603	
				RS/RK	.20294 [*]	.01066	.000	.1678	.2380	
				RS/ISD	-.04464 [*]	.01066	.013	-.0797	-.0095	
				Control/RP	.24057 [*]	.01066	.000	.2055	.2757	
			RS/RK	Control	-.07770 [*]	.01066	.000	-.1128	-.0426	
				RS	-.20294 [*]	.01066	.000	-.2380	-.1678	
				RS/ISD	-.24758 [*]	.01066	.000	-.2827	-.2125	
				Control/RP	.03763 [*]	.01066	.035	.0025	.0727	
			RS/ISD	Control	.16988 [*]	.01066	.000	.1348	.2050	
				RS	.04464 [*]	.01066	.013	.0095	.0797	
				RS/RK	.24758 [*]	.01066	.000	.2125	.2827	
				Control/RP	.28521 [*]	.01066	.000	.2501	.3203	
			Control/RP	Control	-.11533 [*]	.01066	.000	-.1504	-.0802	
				RS	-.24057 [*]	.01066	.000	-.2757	-.2055	
				RS/RK	-.03763 [*]	.01066	.035	-.0727	-.0025	
				RS/ISD	-.28521 [*]	.01066	.000	-.3203	-.2501	
			LSD	Control	RS	-.12523 [*]	.01066	.000	-.1490	-.1015
					RS/RK	.07770 [*]	.01066	.000	.0539	.1015
RS/ISD					-.16988 [*]	.01066	.000	-.1936	-.1461	
Control/RP					.11533 [*]	.01066	.000	.0916	.1391	
RS				Control	.12523 [*]	.01066	.000	.1015	.1490	
				RS/RK	.20294 [*]	.01066	.000	.1792	.2267	
				RS/ISD	-.04464 [*]	.01066	.002	-.0684	-.0209	
				Control/RP	.24057 [*]	.01066	.000	.2168	.2643	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS/RK	Control	-.07770*	.01066	.000	-.1015	-.0539		
		RS	-.20294*	.01066	.000	-.2267	-.1792		
		RS/ISD	-.24758*	.01066	.000	-.2713	-.2238		
		Control/RP	.03763*	.01066	.005	.0139	.0614		
	RS/ISD	Control	.16988*	.01066	.000	.1461	.1936		
		RS	.04464*	.01066	.002	.0209	.0684		
		RS/RK	.24758*	.01066	.000	.2238	.2713		
		Control/RP	.28521*	.01066	.000	.2614	.3090		
	Control/RP	Control	-.11533*	.01066	.000	-.1391	-.0916		
		RS	-.24057*	.01066	.000	-.2643	-.2168		
		RS/RK	-.03763*	.01066	.005	-.0614	-.0139		
		RS/ISD	-.28521*	.01066	.000	-.3090	-.2614		
	Bakingweightloss_Bread	Tukey HSD	Control	RS	.64616	.25217	.153	-.1848	1.4751
				RS/RK	-1.46161*	.25217	.001	-2.2815	-.6217
				RS/ISD	-.05376	.25217	.999	-.8837	.7762
				Control/RP	4.89247*	.25217	.000	4.0626	5.7224
RS			Control	-.64616	.25217	.153	-1.4751	.1848	
			RS/RK	-2.09677*	.25217	.000	-2.9267	-1.2669	
			RS/ISD	-.69892	.25217	.111	-1.5288	.1310	
			Control/RP	4.24731*	.25217	.000	3.4174	5.0772	
RS/RK			Control	1.46161*	.25217	.001	.6217	2.2815	
			RS	2.09677*	.25217	.000	1.2669	2.9267	
			RS/ISD	1.39785*	.25217	.002	.5679	2.2278	
			Control/RP	6.34409*	.25217	.000	5.5142	7.1740	
RS/ISD			Control	.05376	.25217	.999	-.7762	.8837	
			RS	.69892	.25217	.111	-.1310	1.5288	
			RS/RK	-1.39785*	.25217	.002	-2.2278	-.5679	
			Control/RP	4.94624*	.25217	.000	4.1163	5.7762	
Control/RP			Control	-4.89247*	.25217	.000	-5.7224	-4.0626	
			RS	-4.24731*	.25217	.000	-5.0772	-3.4174	
			RS/RK	-6.34409*	.25217	.000	-7.1740	-5.5142	
			RS/ISD	-4.94624*	.25217	.000	-5.7762	-4.1163	
LSD			Control	RS	.64616*	.25217	.028	.0833	1.2070
				RS/RK	-1.46161*	.25217	.000	-2.0135	-.8897
				RS/ISD	-.05376	.25217	.835	-.6156	.5081
				Control/RP	4.89247*	.25217	.000	4.3306	5.4543
		RS	Control	-.64616*	.25217	.028	-1.2070	-.0833	
			RS/RK	-2.09677*	.25217	.000	-2.6587	-1.5349	
			RS/ISD	-.69892*	.25217	.020	-1.2608	-.1370	
			Control/RP	4.24731*	.25217	.000	3.6854	4.8092	
		RS/RK	Control	1.46161*	.25217	.000	.8897	2.0135	
			RS	2.09677*	.25217	.000	1.5349	2.6587	
			RS/ISD	1.39785*	.25217	.000	.8360	1.9597	
			Control/RP	6.34409*	.25217	.000	5.7822	6.9060	
		RS/ISD	Control	.05376	.25217	.835	-.5081	.6156	
			RS	.69892*	.25217	.020	.1370	1.2608	
			RS/RK	-1.39785*	.25217	.000	-1.9597	-.8360	
			Control/RP	4.94624*	.25217	.000	4.3844	5.5081	
		Control/RP	Control	-4.89247*	.25217	.000	-5.4543	-4.3306	
			RS	-4.24731*	.25217	.000	-4.8092	-3.6854	
			RS/RK	-6.34409*	.25217	.000	-6.9060	-5.7822	
			RS/ISD	-4.94624*	.25217	.000	-5.5081	-4.3844	

*. The mean difference is significant at the 0.05 level.

Loafweight_Bread

		Subset for alpha = 0.05			
Bread		N	1	2	3
Tukey HSD ^a	RS/RK	3	525.6667		
	RS/ISD	3		534.3333	
	Control	3		534.6667	
	RS	3		538.6667	
	Control/RP	3			565.0000
	Sig.		1.000	.111	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Specificvolume_Bread

		Subset for alpha = 0.05					
Bread		N	1	2	3	4	5
Tukey HSD ^a	Control/RP	3	2.1976				
	RS/RK	3		2.2353			
	Control	3			2.3130		
	RS	3				2.4382	
	RS/ISD	3					2.4828
	Sig.		1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Loafvolume_Bread

		Subset for alpha = 0.05			
Bread		N	1	2	3
Tukey HSD ^a	RS/RK	3	1175.0000		
	Control	3		1236.6667	
	Control/RP	3		1241.6667	
	RS	3			1313.3333
	RS/ISD	3			1326.6667
	Sig.		1.000	.846	.124

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

Bakingweightloss_Bread

		Subset for alpha = 0.05			
Bread		N	1	2	3
Tukey HSD ^a	Control/RP	3	8.8710		
	RS	3		13.1183	
	Control	3		13.7634	
	RS/ISD	3		13.8172	
	RS/RK	3			15.2151
	Sig.		1.000	.111	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 3.000.

D.10 Statistical analysis of water activity (Day 0 and Day 7) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Wateractivity_Day0_Bread	Control	3	.9781	.00250	.00144	.9719	.9843	.98	.98
	RS	3	.9790	.00169	.00098	.9748	.9832	.98	.98
	RS/RK	3	.9810	.00066	.00038	.9794	.9826	.98	.98
	RS/ISD	3	.9817	.00101	.00058	.9792	.9842	.98	.98
	Control/RP	3	.9787	.00309	.00178	.9711	.9864	.98	.98
	Total	15	.9797	.00222	.00057	.9785	.9809	.98	.98
Wateractivity_Day7_Bread	Control	3	.9739	.00397	.00229	.9640	.9837	.97	.98
	RS	3	.9795	.00162	.00093	.9755	.9835	.98	.98
	RS/RK	3	.9841	.00053	.00031	.9828	.9854	.98	.98
	RS/ISD	3	.9811	.00075	.00044	.9792	.9830	.98	.98
	Control/RP	3	.9772	.00079	.00046	.9752	.9792	.98	.98
	Total	15	.9792	.00397	.00102	.9770	.9814	.97	.98

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Wateractivity_Day0_Bread	Between Groups	.000	4	.000	1.791	.207
	Within Groups	.000	10	.000		
	Total	.000	14			
Wateractivity_Day7_Bread	Between Groups	.000	4	.000	11.357	.001
	Within Groups	.000	10	.000		
	Total	.000	14			

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval						
						Lower Bound	Upper Bound					
Wateractivity_Day0_Bread	Tukey HSD	Control	RS	-.00087	.00164	.982	-.0063	.0045				
			RS/RK	-.00290	.00164	.438	-.0083	.0025				
			RS/ISD	-.00357	.00164	.262	-.0090	.0018				
			Control/RP	-.00063	.00164	.994	-.0060	.0048				
		RS	Control	.00087	.00164	.982	-.0045	.0063				
			RS/RK	-.00203	.00164	.729	-.0074	.0034				
			RS/ISD	-.00270	.00164	.502	-.0081	.0027				
			Control/RP	.00023	.00164	1.000	-.0052	.0056				
		RS/RK	Control	.00290	.00164	.438	-.0025	.0083				
			RS	.00203	.00164	.729	-.0034	.0074				
			RS/ISD	-.00067	.00164	.993	-.0061	.0047				
			Control/RP	.00227	.00164	.649	-.0031	.0077				
		RS/ISD	Control	.00357	.00164	.262	-.0018	.0090				
			RS	.00270	.00164	.502	-.0027	.0081				
			RS/RK	.00067	.00164	.993	-.0047	.0061				
			Control/RP	.00293	.00164	.427	-.0025	.0083				
		Control/RP	Control	.00063	.00164	.994	-.0048	.0060				
			RS	-.00023	.00164	1.000	-.0056	.0052				
			RS/RK	-.00227	.00164	.649	-.0077	.0031				
			RS/ISD	-.00293	.00164	.427	-.0083	.0025				
		LSD	LSD	Control	RS	-.00087	.00164	.608	-.0045	.0028		
					RS/RK	-.00290	.00164	.107	-.0065	.0007		
					RS/ISD	-.00357	.00164	.054	-.0072	.0001		
					Control/RP	-.00063	.00164	.707	-.0043	.0030		
				RS	Control	.00087	.00164	.608	-.0028	.0045		
					RS/RK	-.00203	.00164	.242	-.0057	.0016		
					RS/ISD	-.00270	.00164	.130	-.0063	.0009		
					Control/RP	.00023	.00164	.889	-.0034	.0039		
				RS/RK	Control	.00290	.00164	.107	-.0007	.0065		
					RS	.00203	.00164	.242	-.0016	.0057		
					RS/ISD	-.00067	.00164	.692	-.0043	.0030		
					Control/RP	.00227	.00164	.196	-.0014	.0059		
				RS/ISD	Control	.00357	.00164	.054	-.0001	.0072		
					RS	.00270	.00164	.130	-.0009	.0063		
					RS/RK	.00067	.00164	.692	-.0030	.0043		
					Control/RP	.00293	.00164	.103	-.0007	.0066		
				Control/RP	Control	.00063	.00164	.707	-.0030	.0043		
					RS	-.00023	.00164	.889	-.0039	.0034		
					RS/RK	-.00227	.00164	.196	-.0059	.0014		
					RS/ISD	-.00293	.00164	.103	-.0066	.0007		
				Wateractivity_Day7_Bread	Tukey HSD	Control	RS	-.00567	.00163	.037	-.0110	-.0003
							RS/RK	-.01023	.00163	.001	-.0156	-.0049
							RS/ISD	-.00723	.00163	.009	-.0126	-.0019
							Control/RP	-.00333	.00163	.312	-.0087	.0020
						RS	Control	.00567	.00163	.037	.0003	.0110
							RS/RK	-.00457	.00163	.106	-.0099	.0008
							RS/ISD	-.00157	.00163	.866	-.0069	.0038
							Control/RP	.00233	.00163	.622	-.0030	.0077
RS/RK	Control					.01023	.00163	.001	.0049	.0156		
	RS					.00457	.00163	.106	-.0008	.0099		
	RS/ISD					.00300	.00163	.403	-.0024	.0084		
	Control/RP					.00690	.00163	.012	.0015	.0123		
RS/ISD	Control					.00723	.00163	.009	.0019	.0126		
	RS					.00157	.00163	.866	-.0038	.0069		
	RS/RK					-.00300	.00163	.403	-.0084	.0024		
	Control/RP					.00390	.00163	.193	-.0015	.0093		
Control/RP	Control					.00333	.00163	.312	-.0020	.0087		
	RS					-.00233	.00163	.622	-.0077	.0030		

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	Control	RS/RK	-.00690*	.00163	.012	-.0123	-.0015
		RS/ISD	-.00390	.00163	.193	-.0093	.0015
	RS	-.00567*	.00163	.006	-.0093	-.0020	
	RS	RS/RK	-.01023*	.00163	.000	-.0139	-.0066
		RS/ISD	-.00723*	.00163	.001	-.0109	-.0036
		Control/RP	-.00333	.00163	.068	-.0070	.0003
		Control	.00567*	.00163	.006	.0020	.0093
	RS/RK	RS/RK	-.00457*	.00163	.019	-.0082	-.0009
		RS/ISD	-.00157	.00163	.358	-.0052	.0021
		Control/RP	.00233	.00163	.182	-.0013	.0060
		Control	.01023*	.00163	.000	.0066	.0139
	RS/ISD	RS	.00457*	.00163	.019	.0009	.0082
		RS/ISD	.00300	.00163	.095	-.0006	.0066
		Control/RP	.00690*	.00163	.002	.0033	.0105
		Control	.00723*	.00163	.001	.0036	.0109
	Control/RP	RS	.00157	.00163	.358	-.0021	.0052
		RS/RK	-.00300	.00163	.095	-.0066	.0006
		Control/RP	.00390*	.00163	.038	.0003	.0075
		Control	.00333	.00163	.068	-.0003	.0070
	RS	RS	-.00233	.00163	.182	-.0060	.0013
		RS/RK	-.00690*	.00163	.002	-.0105	-.0033
		RS/ISD	-.00390*	.00163	.038	-.0075	-.0003
		Control/RP	-.00333	.00163	.068	-.0003	.0070

*. The mean difference is significant at the 0.05 level.

Wateractivity_Day0_Bread

Tukey HSD ^a	Bread	N	Subset for alpha = 0.05	
			1	
	Control	3	.9781	
	Control/RP	3	.9787	
	RS	3	.9790	
	RS/RK	3	.9810	
	RS/ISD	3	.9817	
	Sig.		.262	

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Wateractivity_Day7_Bread

Tukey HSD ^a	Bread	N	Subset for alpha = 0.05		
			1	2	3
	Control	3	.9739		
	Control/RP	3	.9772		
	RS	3		.9795	.9795
	RS/ISD	3		.9811	.9811
	RS/RK	3			.9841
	Sig.		.312	.193	.106

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

D.11 Statistical analysis of texture profile analysis (TPA) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

		Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Hardness_Bread	Control	12	16.3008	2.83475	.81832	14.4997	18.1019	12.60	21.41
	RS	12	14.1724	2.25780	.65177	12.7378	15.6069	9.96	19.12
	RS/RK	12	17.1595	2.73664	.79000	15.4207	18.8983	13.85	22.03
	RS/ISD	12	16.6900	1.27658	.36852	15.8789	17.5011	14.91	18.71
	Control/RP	12	12.8857	1.54271	.44534	11.9055	13.8659	9.88	15.10
	Total	60	15.4417	2.70483	.34919	14.7430	16.1404	9.88	22.03
Springiness_Bread	Control	12	.9496	.01765	.00510	.9384	.9608	.90	.97
	RS	12	.9575	.00711	.00205	.9530	.9620	.94	.97
	RS/RK	12	.9442	.00837	.00241	.9389	.9495	.93	.96
	RS/ISD	12	.9101	.01309	.00378	.9017	.9184	.89	.93
	Control/RP	12	.9487	.00909	.00262	.9430	.9545	.93	.96
	Total	60	.9420	.02016	.00260	.9368	.9472	.89	.97
Cohesiveness_Bread	Control	12	.5619	.03694	.01066	.5384	.5853	.51	.62
	RS	12	.5819	.04766	.01376	.5516	.6122	.52	.67
	RS/RK	12	.6012	.04813	.01389	.5706	.6317	.54	.73
	RS/ISD	12	.5308	.03007	.00868	.5117	.5499	.48	.58
	Control/RP	12	.6636	.05507	.01590	.6286	.6986	.59	.75
	Total	60	.5879	.06206	.00801	.5718	.6039	.48	.75
Gumminess_Bread	Control	12	9.1188	1.41587	.40873	8.2192	10.0184	6.99	12.11
	RS	12	8.1593	.76425	.22062	7.6737	8.6449	6.68	9.88
	RS/RK	12	10.2350	1.18600	.34237	9.4814	10.9885	8.48	11.91
	RS/ISD	12	8.8325	.43200	.12471	8.5580	9.1070	7.99	9.59
	Control/RP	12	8.4998	.79767	.23027	7.9930	9.0066	6.98	9.60
	Total	60	8.9691	1.18776	.15334	8.6622	9.2759	6.68	12.11
Chewiness_Bread	Control	12	8.6618	1.37831	.39788	7.7860	9.5375	6.67	11.65
	RS	12	7.8142	.75494	.21793	7.3346	8.2939	6.40	9.53
	RS/RK	12	9.6659	1.13742	.32835	8.9432	10.3886	7.86	11.32
	RS/ISD	12	8.0353	.34600	.09988	7.8155	8.2552	7.33	8.66
	Control/RP	12	8.0647	.77209	.22288	7.5742	8.5553	6.64	9.25
	Total	60	8.4484	1.13680	.14676	8.1547	8.7421	6.40	11.65
Resilience_Bread	Control	12	.2445	.02705	.00781	.2273	.2617	.20	.29
	RS	12	.2609	.02816	.00813	.2430	.2788	.23	.32
	RS/RK	12	.2647	.02278	.00658	.2502	.2792	.23	.31
	RS/ISD	12	.1843	.02258	.00652	.1700	.1987	.14	.23
	Control/RP	12	.2980	.03011	.00869	.2789	.3171	.26	.34
	Total	60	.2422	.02622	.00714	.2262	.2622	.14	.34

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Hardness_Bread	Between Groups	160.694	4	40.174	8.155	.000
	Within Groups	270.955	55	4.926		
	Total	431.650	59			
Springiness_Bread	Between Groups	.016	4	.004	29.923	.000
	Within Groups	.008	55	.000		
	Total	.024	59			
Cohesiveness_Bread	Between Groups	.118	4	.030	14.974	.000
	Within Groups	.109	55	.002		
	Total	.227	59			
Gumminess_Bread	Between Groups	30.234	4	7.559	7.844	.000
	Within Groups	53.001	55	.964		
	Total	83.236	59			
Chewiness_Bread	Between Groups	26.975	4	6.744	7.528	.000
	Within Groups	49.272	55	.896		
	Total	76.246	59			
Resilience_Bread	Between Groups	.084	4	.021	30.264	.000
	Within Groups	.038	55	.001		
	Total	.122	59			

Hardness_Bread

		Subset for alpha = 0.05				
		Bread	N	1	2	3
Tukey HSD ^a	Control/RP	12	12.8857			
	RS	12	14.1724	14.1724		
	Control	12		16.3008	16.3008	
	RS/ISD	12		16.6900	16.6900	
	RS/RK	12			17.1595	
	Sig.			.618	.055	.877

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Springiness_Bread

		Subset for alpha = 0.05			
		Bread	N	1	2
Tukey HSD ^a	RS/ISD	12	.9101		
	RS/RK	12		.9442	
	Control/RP	12		.9487	
	Control	12		.9496	
	RS	12		.9575	
	Sig.			1.000	.054

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Cohesiveness_Bread

		Subset for alpha = 0.05				
		Bread	N	1	2	3
Tukey HSD ^a	RS/ISD	12	.5308			
	Control	12	.5619	.5619		
	RS	12	.5819	.5819		
	RS/RK	12		.6012		
	Control/RP	12			.6636	
	Sig.			.051	.209	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Gumminess_Bread

		Subset for alpha = 0.05			
		Bread	N	1	2
Tukey HSD ^a	RS	12	8.1593		
	Control/RP	12	8.4998		
	RS/ISD	12	8.8325		
	Control	12	9.1188	9.1188	
	RS/RK	12		10.2350	
	Sig.			.132	.054

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Chewiness_Bread

		Subset for alpha = 0.05			
		Bread	N	1	2
Tukey HSD ^a	RS	12	7.8142		
	RS/ISD	12	8.0353		
	Control/RP	12	8.0647		
	Control	12	8.6618	8.6618	
	RS/RK	12		9.6659	
	Sig.			.198	.085

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 12.000.

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Hardness_Bread	Tukey HSD	Control	RS	2.12845	.90613	.145	-.4271	4.6840
			RS/RK	-.85864	.90613	.877	-3.4142	1.6970
			RS/ISD	-.38915	.90613	.993	-2.9447	2.1664
			Control/RP	3.41509 [*]	.90613	.004	.8595	5.9707
		RS	Control	-2.12845	.90613	.145	-4.6840	.4271
			RS/RK	-2.98709 [*]	.90613	.014	-5.5427	-.4315
			RS/ISD	-2.51761	.90613	.055	-5.0732	.0380
			Control/RP	1.28664	.90613	.618	-1.2689	3.8422
		RS/RK	Control	.85864	.90613	.877	-1.6970	3.4142
			RS	2.98709 [*]	.90613	.014	.4315	5.5427
			RS/ISD	.46948	.90613	.985	-2.0861	3.0251
			Control/RP	4.27373 [*]	.90613	.000	1.7181	6.8293
		RS/ISD	Control	.38915	.90613	.993	-2.1664	2.9447
			RS	2.51761	.90613	.055	-.0380	5.0732
			RS/RK	-.46948	.90613	.985	-3.0251	2.0861
			Control/RP	3.80425 [*]	.90613	.001	1.2487	6.3598
	Control/RP	Control	-3.41509 [*]	.90613	.004	-5.9707	-.8595	
		RS	-1.28664	.90613	.618	-3.8422	1.2689	
		RS/RK	-4.27373 [*]	.90613	.000	-6.8293	-1.7181	
		RS/ISD	-3.80425 [*]	.90613	.001	-6.3598	-1.2487	
	LSD	Control	RS	2.12845 [*]	.90613	.022	.3125	3.9444
			RS/RK	-.85864	.90613	.347	-2.6746	.9573
			RS/ISD	-.38915	.90613	.669	-2.2051	1.4268
			Control/RP	3.41509 [*]	.90613	.000	1.5992	5.2310
		RS	Control	-2.12845 [*]	.90613	.022	-3.9444	-.3125
			RS/RK	-2.98709 [*]	.90613	.002	-4.8030	-1.1712
			RS/ISD	-2.51761 [*]	.90613	.007	-4.3335	-.7017
			Control/RP	1.28664	.90613	.161	-.5293	3.1026
		RS/RK	Control	.85864	.90613	.347	-.9573	2.6746
			RS	2.98709 [*]	.90613	.002	1.1712	4.8030
			RS/ISD	.46948	.90613	.606	-1.3464	2.2854
			Control/RP	4.27373 [*]	.90613	.000	2.4578	6.0897

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval				
						Lower Bound	Upper Bound			
	RS/ISD	Control	.38915	.90613	.669	-1.4268	2.2051			
		RS	2.51761*	.90613	.007	.7017	4.3335			
		RS/RK	-.46948	.90613	.606	-2.2854	1.3464			
		Control/RP	3.80425*	.90613	.000	1.9883	5.6202			
	Control/RP	Control	-3.41509*	.90613	.000	-5.2310	-1.5992			
		RS	-1.28664	.90613	.161	-3.1026	.5293			
		RS/RK	-4.27373*	.90613	.000	-6.0897	-2.4578			
		RS/ISD	-3.80425*	.90613	.000	-5.6202	-1.9883			
	Springiness_Bread	Tukey HSD	Control	RS	-.00789	.00478	.473	-.0214	.0056	
				RS/RK	.00543	.00478	.787	-.0081	.0189	
				RS/ISD	.03956*	.00478	.000	.0261	.0530	
				Control/RP	.00089	.00478	1.000	-.0126	.0144	
RS			Control	.00789	.00478	.473	-.0056	.0214		
			RS/RK	.01332	.00478	.054	-.0002	.0268		
			RS/ISD	.04746*	.00478	.000	.0340	.0609		
			Control/RP	.00879	.00478	.363	-.0047	.0223		
RS/RK			Control	-.00543	.00478	.787	-.0189	.0081		
			RS	-.01332	.00478	.054	-.0268	.0002		
			RS/ISD	.03413*	.00478	.000	.0206	.0476		
			Control/RP	-.00454	.00478	.877	-.0180	.0090		
RS/ISD			Control	-.03956*	.00478	.000	-.0530	-.0261		
			RS	-.04746*	.00478	.000	-.0609	-.0340		
			RS/RK	-.03413*	.00478	.000	-.0476	-.0206		
			Control/RP	-.03867*	.00478	.000	-.0522	-.0252		
Control/RP			Control	-.00089	.00478	1.000	-.0144	.0126		
			RS	-.00879	.00478	.363	-.0223	.0047		
			RS/RK	.00454	.00478	.877	-.0090	.0180		
			RS/ISD	.03867*	.00478	.000	.0252	.0522		
LSD			Control	RS	-.00789	.00478	.105	-.0175	.0017	
				RS/RK	.00543	.00478	.261	-.0042	.0150	
				RS/ISD	.03956*	.00478	.000	.0300	.0491	
				Control/RP	.00089	.00478	.853	-.0087	.0105	
		RS	Control	.00789	.00478	.105	-.0017	.0175		
			RS/RK	.01332*	.00478	.007	.0037	.0229		
			RS/ISD	.04746*	.00478	.000	.0379	.0570		
			Control/RP	.00879	.00478	.072	-.0008	.0184		
		RS/RK	Control	-.00543	.00478	.261	-.0150	.0042		
			RS	-.01332*	.00478	.007	-.0229	-.0037		
			RS/ISD	.03413*	.00478	.000	.0246	.0437		
			Control/RP	-.00454	.00478	.347	-.0141	.0050		
		RS/ISD	Control	-.03956*	.00478	.000	-.0491	-.0300		
			RS	-.04746*	.00478	.000	-.0570	-.0379		
			RS/RK	-.03413*	.00478	.000	-.0437	-.0246		
			Control/RP	-.03867*	.00478	.000	-.0483	-.0291		
		Control/RP	Control	-.00089	.00478	.853	-.0105	.0087		
			RS	-.00879	.00478	.072	-.0184	.0008		
			RS/RK	.00454	.00478	.347	-.0050	.0141		
			RS/ISD	.03867*	.00478	.000	.0291	.0483		
		Cohesiveness_Bread	Tukey HSD	Control	RS	-.02002	.01816	.804	-.0712	.0312
					RS/RK	-.03928	.01816	.209	-.0905	.0119
					RS/ISD	.03105	.01816	.436	-.0202	.0823
					Control/RP	-.10170*	.01816	.000	-.1529	-.0505
RS				Control	.02002	.01816	.804	-.0312	.0712	
				RS/RK	-.01926	.01816	.826	-.0705	.0320	
				RS/ISD	.05107	.01816	.051	-.0001	.1023	
				Control/RP	-.08167*	.01816	.000	-.1329	-.0305	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS/RK	Control	.03928	.01816	.209	-.0119	.0905		
		RS	.01926	.01816	.826	-.0320	.0705		
		RS/ISD	.07033 [*]	.01816	.003	.0191	.1215		
		Control/RP	-.06242 [*]	.01816	.010	-.1136	-.0112		
	RS/ISD	Control	-.03105	.01816	.436	-.0823	.0202		
		RS	-.05107	.01816	.051	-.1023	.0001		
		RS/RK	-.07033 [*]	.01816	.003	-.1215	-.0191		
		Control/RP	-.13275 [*]	.01816	.000	-.1840	-.0815		
	Control/RP	Control	.10170 [*]	.01816	.000	.0505	.1529		
		RS	.08167 [*]	.01816	.000	.0305	.1329		
		RS/RK	.06242 [*]	.01816	.010	.0112	.1136		
		RS/ISD	.13275 [*]	.01816	.000	.0815	.1840		
	LSD	Control	RS	-.02002	.01816	.275	-.0664	.0164	
			RS/RK	-.03928 [*]	.01816	.035	-.0757	-.0029	
			RS/ISD	.03105	.01816	.093	-.0053	.0674	
			Control/RP	-.10170 [*]	.01816	.000	-.1381	-.0653	
		RS	Control	.02002	.01816	.275	-.0164	.0564	
			RS/RK	-.01926	.01816	.294	-.0556	.0171	
			RS/ISD	.05107 [*]	.01816	.007	.0147	.0875	
			Control/RP	-.08167 [*]	.01816	.000	-.1181	-.0453	
		RS/RK	Control	.03928 [*]	.01816	.035	.0029	.0757	
			RS	.01926	.01816	.294	-.0171	.0556	
			RS/ISD	.07033 [*]	.01816	.000	.0339	.1067	
			Control/RP	-.06242 [*]	.01816	.001	-.0988	-.0260	
		RS/ISD	Control	-.03105	.01816	.093	-.0674	.0053	
			RS	-.05107 [*]	.01816	.007	-.0875	-.0147	
			RS/RK	-.07033 [*]	.01816	.000	-.1067	-.0339	
			Control/RP	-.13275 [*]	.01816	.000	-.1691	-.0964	
Control/RP		Control	.10170 [*]	.01816	.000	.0653	.1381		
		RS	.08167 [*]	.01816	.000	.0453	.1181		
		RS/RK	.06242 [*]	.01816	.001	.0260	.0988		
		RS/ISD	.13275 [*]	.01816	.000	.0964	.1691		
Gumminess_Bread		Tukey HSD	Control	RS	.95949	.40076	.132	-.1708	2.0898
				RS/RK	-1.11619	.40076	.054	-2.2465	.0141
				RS/ISD	.28632	.40076	.952	-.8440	1.4166
				Control/RP	.61898	.40076	.539	-.5113	1.7493
			RS	Control	-.95949	.40076	.132	-2.0898	.1708
				RS/RK	-2.07568 [*]	.40076	.000	-3.2060	-.9454
				RS/ISD	-.67317	.40076	.455	-1.8034	.4571
				Control/RP	-.34051	.40076	.914	-1.4708	.7898
	RS/RK		Control	1.11619	.40076	.054	-.0141	2.2465	
			RS	2.07568 [*]	.40076	.000	.9454	3.2060	
			RS/ISD	1.40251 [*]	.40076	.008	.2722	2.5328	
			Control/RP	1.73517 [*]	.40076	.001	.6049	2.8654	
	RS/ISD		Control	-.28632	.40076	.952	-1.4166	.8440	
			RS	.67317	.40076	.455	-.4571	1.8034	
			RS/RK	-1.40251 [*]	.40076	.008	-2.5328	-.2722	
			Control/RP	.33266	.40076	.920	-.7976	1.4629	
	Control/RP		Control	-.61898	.40076	.539	-1.7493	.5113	
			RS	.34051	.40076	.914	-.7898	1.4708	
			RS/RK	-1.73517 [*]	.40076	.001	-2.8654	-.6049	
			RS/ISD	-.33266	.40076	.920	-1.4629	.7976	
	LSD		Control	RS	.95949 [*]	.40076	.020	.1563	1.7626
				RS/RK	-1.11619 [*]	.40076	.007	-1.9193	-.3131

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval				
						Lower Bound	Upper Bound			
		RS/ISD	.28632	.40076	.478	-.5168	1.0895			
		Control/RP	.61898	.40076	.128	-.1842	1.4221			
		RS	Control	-.95949*	.40076	.020	-1.7626	-.1563		
			RS/RK	-2.07568*	.40076	.000	-2.8788	-1.2725		
			RS/ISD	-.67317	.40076	.099	-1.4763	.1300		
			Control/RP	-.34051	.40076	.399	-1.1437	.4626		
		RS/RK	Control	1.11619*	.40076	.007	.3131	1.9193		
			RS	2.07568*	.40076	.000	1.2725	2.8788		
			RS/ISD	1.40251*	.40076	.001	.5994	2.2057		
			Control/RP	1.73517*	.40076	.000	.9320	2.5383		
		RS/ISD	Control	-.28632	.40076	.478	-1.0895	.5168		
			RS	.67317	.40076	.099	-.1300	1.4763		
			RS/RK	-1.40251*	.40076	.001	-2.2057	-.5994		
			Control/RP	.33266	.40076	.410	-.4705	1.1358		
		Control/RP	Control	-.61898	.40076	.128	-1.4221	.1842		
			RS	.34051	.40076	.399	-.4626	1.1437		
			RS/RK	-1.73517*	.40076	.000	-2.5383	-.9320		
			RS/ISD	-.33266	.40076	.410	-1.1358	.4705		
		Chewiness_Bread	Tukey HSD	Control	RS	.84756	.38640	.198	-.2422	1.9373
					RS/RK	-1.00413	.38640	.085	-2.0939	.0857
RS/ISD	.62646				.38640	.491	-.4633	1.7162		
Control/RP	.59706				.38640	.538	-.4927	1.6868		
RS	Control			-.84756	.38640	.198	-1.9373	.2422		
	RS/RK			-1.85169*	.38640	.000	-2.9415	-.7619		
	RS/ISD			-.22110	.38640	.979	-1.3109	.8687		
	Control/RP			-.25050	.38640	.966	-1.3403	.8393		
RS/RK	Control			1.00413	.38640	.085	-.0857	2.0939		
	RS			1.85169*	.38640	.000	.7619	2.9415		
	RS/ISD			1.63060*	.38640	.001	.5408	2.7204		
	Control/RP			1.60119*	.38640	.001	.5114	2.6910		
RS/ISD	Control			-.62646	.38640	.491	-1.7162	.4633		
	RS			.22110	.38640	.979	-.8687	1.3109		
	RS/RK			-1.63060*	.38640	.001	-2.7204	-.5408		
	Control/RP			-.02940	.38640	1.000	-1.1192	1.0604		
Control/RP	Control			-.59706	.38640	.538	-1.6868	.4927		
	RS			.25050	.38640	.966	-.8393	1.3403		
	RS/RK			-1.60119*	.38640	.001	-2.6910	-.5114		
	RS/ISD			.02940	.38640	1.000	-1.0604	1.1192		
LSD	Control			RS	RS	.84756*	.38640	.033	.0732	1.6219
					RS/RK	-1.00413*	.38640	.012	-1.7785	-.2298
					RS/ISD	.62646	.38640	.111	-.1479	1.4008
					Control/RP	.59706	.38640	.128	-.1773	1.3714
				RS	Control	-.84756*	.38640	.033	-1.6219	-.0732
					RS/RK	-1.85169*	.38640	.000	-2.6261	-1.0773
					RS/ISD	-.22110	.38640	.570	-.9955	.5533
					Control/RP	-.25050	.38640	.520	-1.0249	.5239
				RS/RK	Control	1.00413*	.38640	.012	.2298	1.7785
					RS	1.85169*	.38640	.000	1.0773	2.6261
					RS/ISD	1.63060*	.38640	.000	.8562	2.4050
					Control/RP	1.60119*	.38640	.000	.8268	2.3756
				RS/ISD	Control	-.62646	.38640	.111	-1.4008	.1479
					RS	.22110	.38640	.570	-.5533	.9955
					RS/RK	-1.63060*	.38640	.000	-2.4050	-.8562
					Control/RP	-.02940	.38640	.940	-.8038	.7450
				Control/RP	Control	-.59706	.38640	.128	-1.3714	.1773
					RS	.25050	.38640	.520	-.5239	1.0249

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
Resilience_Bread	Tukey HSD	Control	RS/RK	-1.60119*	.38640	.000	-2.3756	-.8268	
			RS/ISD	.02940	.38640	.940	-.7460	.8038	
		RS	RS	-.01642	.01074	.549	-.0467	.0139	
			RS/RK	-.02022	.01074	.339	-.0505	.0101	
			RS/ISD	.06014*	.01074	.000	.0299	.0904	
			Control/RP	-.05353*	.01074	.000	-.0838	-.0232	
		RS/RK	Control	.01642	.01074	.549	-.0139	.0467	
			RS/RK	-.00380	.01074	.997	-.0341	.0265	
			RS/ISD	.07656*	.01074	.000	.0463	.1068	
			Control/RP	-.03711*	.01074	.009	-.0674	-.0068	
		RS/ISD	Control	.02022	.01074	.339	-.0101	.0505	
			RS	.00380	.01074	.997	-.0265	.0341	
			RS/ISD	.08036*	.01074	.000	.0501	.1106	
			Control/RP	-.03331*	.01074	.024	-.0636	-.0030	
		Control/RP	Control	-.06014*	.01074	.000	-.0904	-.0299	
			RS	-.07656*	.01074	.000	-.1068	-.0463	
			RS/RK	-.08036*	.01074	.000	-.1106	-.0501	
			Control/RP	-.11367*	.01074	.000	-.1440	-.0834	
		LSD	Control	Control	.05353*	.01074	.000	.0232	.0838
				RS	.03711*	.01074	.009	.0068	.0674
				RS/RK	.03331*	.01074	.024	.0030	.0636
				RS/ISD	.11367*	.01074	.000	.0834	.1440
		RS	Control	RS	-.01642	.01074	.132	-.0379	.0051
			RS/RK	RS/RK	-.02022	.01074	.065	-.0417	.0013
			RS/ISD	RS/ISD	.06014*	.01074	.000	.0386	.0817
			Control/RP	Control/RP	-.05353*	.01074	.000	-.0751	-.0320
		RS/RK	Control	Control	.01642	.01074	.132	-.0051	.0379
			RS/RK	RS/RK	-.00380	.01074	.725	-.0253	.0177
			RS/ISD	RS/ISD	.07656*	.01074	.000	.0550	.0981
			Control/RP	Control/RP	-.03711*	.01074	.001	-.0586	-.0156
		RS/ISD	Control	Control	.02022	.01074	.065	-.0013	.0417
			RS	RS	.00380	.01074	.725	-.0177	.0253
			RS/ISD	RS/ISD	.08036*	.01074	.000	.0588	.1019
			Control/RP	Control/RP	-.03331*	.01074	.003	-.0548	-.0118
		Control/RP	Control	Control	-.06014*	.01074	.000	-.0817	-.0386
			RS	RS	-.07656*	.01074	.000	-.0981	-.0550
			RS/RK	RS/RK	-.08036*	.01074	.000	-.1019	-.0588
			Control/RP	Control/RP	-.11367*	.01074	.000	-.1352	-.0921
		LSD	Control	Control	.05353*	.01074	.000	.0320	.0751
				RS	.03711*	.01074	.001	.0156	.0586
RS/RK	.03331*			.01074	.003	.0118	.0548		
RS/ISD	.11367*			.01074	.000	.0921	.1352		

*. The mean difference is significant at the 0.05 level.

D.12 Statistical analysis of crumb and crust colour parameters (L* - lightness, a* - redness and b* - yellowness) of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

Descriptives

		N	Mean	Std. Deviation	Std. Error	95 % Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Crumbcolour_L_Bread	Control	9	65.2078	.77802	.25934	64.6097	65.8058	64.27	66.25
	RS	9	71.0122	1.55665	.51888	69.8157	72.2088	69.48	73.38
	RS/RK	9	70.0444	.11907	.03969	69.9529	70.1360	69.90	70.24
	RS/ISD	9	65.8244	.25190	.08397	65.6308	66.0181	65.28	65.99
	Control/RP	9	64.0356	.31694	.10565	63.7919	64.2792	63.71	64.72
	Total	45	67.2249	2.90811	.43352	66.3512	68.0986	63.71	73.38
Crumbcolour_a_Bread	Control	9	2.3422	.27999	.09333	2.1270	2.5574	2.01	2.59
	RS	9	-.6444	.19673	.06558	-.7957	-.4932	-.90	-.44
	RS/RK	9	-.2167	.01000	.00333	-.2244	-.2090	-.23	-.20
	RS/ISD	9	-.2744	.11959	.03986	-.3664	-.1825	-.36	-.04
	Control/RP	9	2.0856	.02603	.00868	2.0655	2.1056	2.04	2.14
	Total	45	.6584	1.30476	.19450	.2665	1.0504	-.90	2.59
Crumbcolour_b_Bread	Control	9	19.8089	.55952	.18651	19.3788	20.2390	19.42	20.73
	RS	9	13.4478	1.37696	.45899	12.3894	14.5062	11.97	14.99
	RS/RK	9	12.2433	.02958	.00986	12.2206	12.2661	12.17	12.26
	RS/ISD	9	10.8522	.19734	.06578	10.7005	11.0039	10.55	11.06
	Control/RP	9	18.5811	.15317	.05106	18.4634	18.6988	18.21	18.70
	Total	45	14.9867	3.65138	.54432	13.8897	16.0837	10.55	20.73

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Crumbcolour_L_Bread	Between Groups	346.461	4	86.615	135.059	.000
	Within Groups	25.853	40	.641		
	Total	372.113	44			
Crumbcolour_a_Bread	Between Groups	73.848	4	18.462	698.381	.000
	Within Groups	1.057	40	.026		
	Total	74.906	44			
Crumbcolour_b_Bread	Between Groups	568.454	4	142.113	312.700	.000
	Within Groups	18.179	40	.454		
	Total	586.633	44			

Crumbcolour_L_Bread

		Subset for alpha = 0.05		
Bread	N	1	2	3
Tukey HSD ^a	Control/RP	9	64.0356	
	Control	9		65.2078
	RS/ISD	9		65.8244
	RS/RK	9		70.0444
	RS	9		71.0122
	Sig.		1.000	.486

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Crumbcolour_a_Bread

		Subset for alpha = 0.05			
Bread	N	1	2	3	4
Tukey HSD ^a	RS	9	-.6444		
	RS/ISD	9		-.2744	
	RS/RK	9		-.2167	
	Control/RP	9			2.0856
	Control	9			2.3422
	Sig.		1.000	.942	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Crumbcolour_b_Bread

		Subset for alpha = 0.05				
Bread	N	1	2	3	4	5
Tukey HSD ^a	RS/ISD	9	10.8522			
	RS/RK	9		12.2433		
	RS	9			13.4478	
	Control/RP	9				18.5811
	Control	9				19.8089
	Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Multiple Comparisons

Dependent Variable		(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
							Lower Bound	Upper Bound	
Crumbcolour_L_Bread	Tukey HSD	Control	RS	-5.80444 ^a	.37751	.000	-6.8826	-4.7262	
			RS/RK	-4.83667 ^a	.37751	.000	-5.9149	-3.7585	
			RS/ISD	-.61667	.37751	.486	-1.6949	.4615	
			Control/RP	1.17222 ^b	.37751	.027	.0940	2.2504	
		RS	Control	5.80444 ^a	.37751	.000	4.7262	6.8826	
			RS/RK	.96778	.37751	.097	-.1104	2.0460	
			RS/ISD	5.18778 ^a	.37751	.000	4.1096	6.2660	
			Control/RP	6.97667 ^a	.37751	.000	5.8985	8.0549	
		RS/RK	Control	4.83667 ^a	.37751	.000	3.7585	5.9149	
			RS	-.96778	.37751	.097	-2.0460	.1104	
			RS/ISD	4.22000 ^a	.37751	.000	3.1418	5.2982	
			Control/RP	6.00889 ^a	.37751	.000	4.9307	7.0871	
		RS/ISD	Control	.61667	.37751	.486	-.4615	1.6949	
			RS	-5.18778 ^a	.37751	.000	-6.2660	-4.1096	
			RS/RK	-4.22000 ^a	.37751	.000	-5.2982	-3.1418	
			Control/RP	1.78889 ^a	.37751	.000	.7107	2.8671	
		Control/RP	Control	-1.17222 ^b	.37751	.027	-2.2504	-.0940	
			RS	-6.97667 ^a	.37751	.000	-8.0549	-5.8985	
			RS/RK	-6.00889 ^a	.37751	.000	-7.0871	-4.9307	
			RS/ISD	-1.78889 ^a	.37751	.000	-2.8671	-.7107	
	LSD	Control	RS	-5.80444 ^a	.37751	.000	-6.5674	-5.0415	
			RS/RK	-4.83667 ^a	.37751	.000	-5.5996	-4.0737	
			RS/ISD	-.61667	.37751	.110	-1.3796	.1463	
			Control/RP	1.17222 ^b	.37751	.003	.4092	1.9352	
		RS	Control	5.80444 ^a	.37751	.000	5.0415	6.5674	
			RS/RK	.96778 ^a	.37751	.014	.2048	1.7308	
			RS/ISD	5.18778 ^a	.37751	.000	4.4248	5.9508	
			Control/RP	6.97667 ^a	.37751	.000	6.2137	7.7396	
		RS/RK	Control	4.83667 ^a	.37751	.000	4.0737	5.5996	
			RS	-.96778 ^a	.37751	.014	-1.7308	-.2048	
			RS/ISD	4.22000 ^a	.37751	.000	3.4670	4.9830	
			Control/RP	6.00889 ^a	.37751	.000	5.2459	6.7719	
		RS/ISD	Control	.61667	.37751	.110	-.1463	1.3796	
			RS	-5.18778 ^a	.37751	.000	-5.9508	-4.4248	
			RS/RK	-4.22000 ^a	.37751	.000	-4.9830	-3.4570	
			Control/RP	1.78889 ^a	.37751	.000	1.0259	2.5519	
		Control/RP	Control	-1.17222 ^b	.37751	.003	-1.9352	-.4092	
			RS	-6.97667 ^a	.37751	.000	-7.7396	-6.2137	
			RS/RK	-6.00889 ^a	.37751	.000	-6.7719	-5.2459	
			RS/ISD	-1.78889 ^a	.37751	.000	-2.5519	-1.0259	
	Crumbcolour_a_Bread	Tukey HSD	Control	RS	2.98667 ^a	.07665	.000	2.7678	3.2056
				RS/RK	2.55889 ^a	.07665	.000	2.3400	2.7778
				RS/ISD	2.61667 ^a	.07665	.000	2.3978	2.8356
				Control/RP	.25667 ^a	.07665	.014	.0378	.4756
RS			Control	-2.98667 ^a	.07665	.000	-3.2056	-2.7678	
			RS/RK	-.42778 ^a	.07665	.000	-.6467	-.2089	
			RS/ISD	-.37000 ^a	.07665	.000	-.5889	-.1511	
			Control/RP	-2.73000 ^a	.07665	.000	-2.9489	-2.5111	
RS/RK			Control	-2.55889 ^a	.07665	.000	-2.7778	-2.3400	
			RS	.42778 ^a	.07665	.000	.2089	.6467	
			RS/ISD	.05778	.07665	.942	-.1611	.2767	
			Control/RP	-2.30222 ^a	.07665	.000	-2.5211	-2.0833	
RS/ISD			Control	-2.61667 ^a	.07665	.000	-2.8356	-2.3978	
			RS	.37000 ^a	.07665	.000	.1511	.5889	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval				
						Lower Bound	Upper Bound			
	LSD	Control/RP	RS/RK	-.05778	.07665	.942	-.2767	.1611		
			Control/RP	-2.36000 [*]	.07665	.000	-2.5789	-2.1411		
		Control/RP	Control	-.25667 [*]	.07665	.014	-.4756	-.0378		
			RS	2.73000 [*]	.07665	.000	2.5111	2.9489		
		Control/RP	RS/RK	2.30222 [*]	.07665	.000	2.0833	2.5211		
			RS/ISD	2.36000 [*]	.07665	.000	2.1411	2.5789		
		Control	RS	2.98667 [*]	.07665	.000	2.8318	3.1416		
			RS/RK	2.55889 [*]	.07665	.000	2.4040	2.7138		
		Control	RS/ISD	2.61667 [*]	.07665	.000	2.4618	2.7716		
			Control/RP	.25667 [*]	.07665	.002	.1018	.4116		
		RS	Control	-2.98667 [*]	.07665	.000	-3.1416	-2.8318		
			RS/RK	-.42778 [*]	.07665	.000	-.5827	-.2729		
		RS	RS/ISD	-.37000 [*]	.07665	.000	-.5249	-.2151		
			Control/RP	-2.73000 [*]	.07665	.000	-2.8849	-2.5751		
		RS/RK	Control	-2.55889 [*]	.07665	.000	-2.7138	-2.4040		
			RS	.42778 [*]	.07665	.000	.2729	.5827		
		RS/RK	RS/ISD	.05778	.07665	.455	-.0971	.2127		
			Control/RP	-2.30222 [*]	.07665	.000	-2.4571	-2.1473		
		RS/ISD	Control	-2.61667 [*]	.07665	.000	-2.7716	-2.4618		
			RS	.37000 [*]	.07665	.000	.2151	.5249		
		RS/ISD	RS/RK	-.05778	.07665	.455	-.2127	.0971		
			Control/RP	-2.36000 [*]	.07665	.000	-2.5149	-2.2051		
		Control/RP	Control	-.25667 [*]	.07665	.002	-.4116	-.1018		
			RS	2.73000 [*]	.07665	.000	2.5751	2.8849		
		Control/RP	RS/RK	2.30222 [*]	.07665	.000	2.1473	2.4571		
			RS/ISD	2.36000 [*]	.07665	.000	2.2051	2.5149		
		Crumbcolour_b_Bread	Tukey HSD	Control	RS	6.36111 [*]	.31780	.000	5.4535	7.2688
					RS/RK	7.56556 [*]	.31780	.000	6.6579	8.4732
					RS/ISD	8.95667 [*]	.31780	.000	8.0490	9.8643
					Control/RP	1.22778 [*]	.31780	.003	.3201	2.1354
				RS	Control	-6.36111 [*]	.31780	.000	-7.2688	-5.4535
					RS/RK	1.20444 [*]	.31780	.004	.2968	2.1121
					RS/ISD	2.59556 [*]	.31780	.000	1.6879	3.5032
					Control/RP	-5.13333 [*]	.31780	.000	-6.0410	-4.2257
				RS/RK	Control	-7.56556 [*]	.31780	.000	-8.4732	-6.6579
					RS	-1.20444 [*]	.31780	.004	-2.1121	-.2968
					RS/ISD	1.39111 [*]	.31780	.001	.4835	2.2988
					Control/RP	-6.33778 [*]	.31780	.000	-7.2454	-5.4301
				RS/ISD	Control	-8.95667 [*]	.31780	.000	-9.8643	-8.0490
					RS	-2.59556 [*]	.31780	.000	-3.5032	-1.6879
RS/RK	-1.39111 [*]				.31780	.001	-2.2988	-.4835		
Control/RP	-7.72889 [*]				.31780	.000	-8.6365	-6.8212		
Control/RP	Control			-1.22778 [*]	.31780	.003	-2.1354	-.3201		
	RS			5.13333 [*]	.31780	.000	4.2257	6.0410		
	RS/RK			6.33778 [*]	.31780	.000	5.4301	7.2454		
	RS/ISD			7.72889 [*]	.31780	.000	6.8212	8.6365		
LSD	Control			RS	6.36111 [*]	.31780	.000	5.7188	7.0034	
				RS/RK	7.56556 [*]	.31780	.000	6.9233	8.2078	
				RS/ISD	8.95667 [*]	.31780	.000	8.3144	9.5990	
				Control/RP	1.22778 [*]	.31780	.000	.5855	1.8701	
	RS			Control	-6.36111 [*]	.31780	.000	-7.0034	-5.7188	
				RS/RK	1.20444 [*]	.31780	.000	.5622	1.8467	
				RS/ISD	2.59556 [*]	.31780	.000	1.9533	3.2378	
				Control/RP	-5.13333 [*]	.31780	.000	-5.7756	-4.4910	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
	RS/RK	Control	-7.56556*	.31780	.000	-8.2078	-6.9233
		RS	-1.20444*	.31780	.000	-1.8467	-.5622
		RS/ISD	1.39111*	.31780	.000	.7488	2.0334
		Control/RP	-6.33778*	.31780	.000	-6.9801	-5.6955
	RS/ISD	Control	-8.95667*	.31780	.000	-9.5990	-8.3144
		RS	-2.59556*	.31780	.000	-3.2378	-1.9533
		RS/RK	-1.39111*	.31780	.000	-2.0334	-.7488
		Control/RP	-7.72889*	.31780	.000	-8.3712	-7.0866
	Control/RP	Control	-1.22778*	.31780	.000	-1.8701	-.5855
		RS	5.13333*	.31780	.000	4.4910	5.7756
		RS/RK	6.33778*	.31780	.000	5.6955	6.9801
		RS/ISD	7.72889*	.31780	.000	7.0866	8.3712

*. The mean difference is significant at the 0.05 level.

Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Crustcolour_L_Bread	Control	9	51.8200	.94672	.31557	51.0923	52.5477	50.03	52.88
	RS	9	56.9944	.71670	.23890	56.4435	57.5453	56.11	57.76
	RS/RK	9	57.6689	.77864	.25955	57.0704	58.2674	56.65	58.45
	RS/ISD	9	46.6522	.78783	.26261	46.0466	47.2578	45.54	47.40
	Control/RP	9	50.5789	.16458	.05486	50.4524	50.7054	50.39	50.87
	Total	45	52.7429	4.22670	.63008	51.4730	54.0127	45.54	58.45
Crustcolour_a_Bread	Control	9	10.0844	.49005	.16335	9.7078	10.4611	9.57	10.92
	RS	9	10.4978	.29158	.09719	10.2736	10.7219	10.00	10.88
	RS/RK	9	7.7333	1.40852	.46951	6.8506	8.8160	6.45	9.60
	RS/ISD	9	9.5622	2.36132	.78711	7.7471	11.3773	7.88	12.75
	Control/RP	9	9.5189	.07149	.02383	9.4639	9.5738	9.36	9.59
	Total	45	9.4793	1.53196	.22837	9.0191	9.9396	6.45	12.75
Crustcolour_b_Bread	Control	9	26.2633	.58069	.19356	25.8170	26.7097	25.38	26.99
	RS	9	27.1289	.50627	.16876	26.7397	27.5180	26.56	27.75
	RS/RK	9	26.4122	.35520	.11840	26.1392	26.6853	25.93	26.92
	RS/ISD	9	20.3133	1.33825	.44608	19.2847	21.3420	19.12	22.15
	Control/RP	9	21.9800	.18138	.06046	21.8406	22.1194	21.52	22.10
	Total	45	24.4196	2.85266	.42525	23.5625	25.2766	19.12	27.75

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Crustcolour_L_Bread	Between Groups	764.748	4	191.187	358.839	.000
	Within Groups	21.312	40	.533		
	Total	786.060	44			
Crustcolour_a_Bread	Between Groups	40.143	4	10.036	6.360	.000
	Within Groups	63.120	40	1.578		
	Total	103.263	44			
Crustcolour_b_Bread	Between Groups	337.709	4	84.427	165.966	.000
	Within Groups	20.348	40	.509		
	Total	358.057	44			

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval						
						Lower Bound	Upper Bound					
Crustcolour_L_Bread	Tukey HSD	Control	RS	-5.17444 [*]	.34409	.000	-6.1572	-4.1917				
			RS/RK	-5.84889 [*]	.34409	.000	-6.8316	-4.8661				
			RS/ISD	5.16778 [*]	.34409	.000	4.1850	6.1505				
			Control/RP	1.24111 [*]	.34409	.007	.2584	2.2239				
		RS	Control	5.17444 [*]	.34409	.000	4.1917	6.1572				
			RS/RK	-.67444	.34409	.304	-1.6572	.3083				
			RS/ISD	10.34222 [*]	.34409	.000	9.3595	11.3250				
			Control/RP	6.41556 [*]	.34409	.000	5.4328	7.3983				
		RS/RK	Control	5.84889 [*]	.34409	.000	4.8661	6.8316				
			RS	.67444	.34409	.304	-.3083	1.6572				
			RS/ISD	11.01667 [*]	.34409	.000	10.0339	11.9994				
			Control/RP	7.09000 [*]	.34409	.000	6.1072	8.0728				
		RS/ISD	Control	-5.16778 [*]	.34409	.000	-6.1505	-4.1850				
			RS	-10.34222 [*]	.34409	.000	-11.3250	-9.3595				
			RS/RK	-11.01667 [*]	.34409	.000	-11.9994	-10.0339				
			Control/RP	-3.92667 [*]	.34409	.000	-4.9094	-2.9439				
		Control/RP	Control	-1.24111 [*]	.34409	.007	-2.2239	-.2584				
			RS	-6.41556 [*]	.34409	.000	-7.3983	-5.4328				
			RS/RK	-7.09000 [*]	.34409	.000	-8.0728	-6.1072				
			RS/ISD	3.92667 [*]	.34409	.000	2.9439	4.9094				
		LSD	LSD	Control	RS	-5.17444 [*]	.34409	.000	-5.8699	-4.4790		
					RS/RK	-5.84889 [*]	.34409	.000	-6.5443	-5.1535		
					RS/ISD	5.16778 [*]	.34409	.000	4.4723	5.8632		
					Control/RP	1.24111 [*]	.34409	.001	.5457	1.9365		
				RS	Control	5.17444 [*]	.34409	.000	4.4790	5.8699		
					RS/RK	-.67444	.34409	.057	-1.3699	.0210		
					RS/ISD	10.34222 [*]	.34409	.000	9.6468	11.0377		
					Control/RP	6.41556 [*]	.34409	.000	5.7201	7.1110		
				RS/RK	Control	5.84889 [*]	.34409	.000	5.1535	6.5443		
					RS	.67444	.34409	.057	-.0210	1.3699		
					RS/ISD	11.01667 [*]	.34409	.000	10.3212	11.7121		
					Control/RP	7.09000 [*]	.34409	.000	6.3946	7.7854		
				RS/ISD	Control	-5.16778 [*]	.34409	.000	-5.8632	-4.4723		
					RS	-10.34222 [*]	.34409	.000	-11.0377	-9.6468		
					RS/RK	-11.01667 [*]	.34409	.000	-11.7121	-10.3212		
					Control/RP	-3.92667 [*]	.34409	.000	-4.6221	-3.2312		
				Control/RP	Control	-1.24111 [*]	.34409	.001	-1.9365	-.5457		
					RS	-6.41556 [*]	.34409	.000	-7.1110	-5.7201		
					RS/RK	-7.09000 [*]	.34409	.000	-7.7854	-6.3946		
					RS/ISD	3.92667 [*]	.34409	.000	3.2312	4.6221		
				Crustcolour_a_Bread	Tukey HSD	Control	RS	-.41333	.59217	.956	-2.1046	1.2780
							RS/RK	2.35111 [*]	.59217	.003	.6598	4.0424
							RS/ISD	.52222	.59217	.902	-1.1691	2.2135
							Control/RP	.56556	.59217	.873	-1.1257	2.2569
						RS	Control	.41333	.59217	.956	-1.2780	2.1046
							RS/RK	2.76444 [*]	.59217	.000	1.0731	4.4557
							RS/ISD	.93556	.59217	.519	-.7557	2.6269
							Control/RP	.97889	.59217	.474	-.7124	2.6702
RS/RK	Control					-2.35111 [*]	.59217	.003	-4.0424	-.6598		
	RS					-2.76444 [*]	.59217	.000	-4.4557	-1.0731		
	RS/ISD					-1.82889 [*]	.59217	.028	-3.5202	-.1376		
	Control/RP					-1.78556 [*]	.59217	.034	-3.4769	-.0943		
RS/ISD	Control					-.52222	.59217	.902	-2.2135	1.1691		
	RS					-.93556	.59217	.519	-2.6269	.7557		

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95 % Confidence Interval			
						Lower Bound	Upper Bound		
Crustcolour_b_Bread	LSD	Control/RP	RS/RK	1.82889 [*]	.59217	.028	.1376	3.5202	
			Control/RP	.04333	.59217	1.000	-1.6480	1.7346	
			Control	-.56556	.59217	.873	-2.2569	1.1257	
			RS	-.97889	.59217	.474	-2.6702	.7124	
		RS/RK	RS/RK	1.78556 [*]	.59217	.034	.0943	3.4769	
			RS/ISD	-.04333	.59217	1.000	-1.7346	1.6480	
			Control	RS	-.41333	.59217	.489	-1.6102	.7835
			RS/RK	2.35111 [†]	.59217	.000	1.1543	3.5479	
		RS/ISD	RS/ISD	.52222	.59217	.383	-.6746	1.7190	
			Control/RP	.56556	.59217	.345	-.6313	1.7624	
			Control	RS	.41333	.59217	.489	-.7835	1.6102
			RS/RK	2.76444 [*]	.59217	.000	1.5676	3.9613	
		RS/RK	RS/ISD	.93556	.59217	.122	-.2613	2.1324	
			Control/RP	.97889	.59217	.106	-.2179	2.1757	
			Control	RS	-2.35111 [†]	.59217	.000	-3.5479	-1.1543
			RS	-2.76444 [*]	.59217	.000	-3.9613	-1.5676	
		RS/ISD	RS/ISD	-1.82889 [*]	.59217	.004	-3.0257	-.6321	
			Control/RP	-1.78556 [*]	.59217	.004	-2.9824	-.5887	
			Control	RS	-.52222	.59217	.383	-1.7190	.6746
			RS	-.93556	.59217	.122	-2.1324	.2613	
		Control/RP	RS/RK	1.82889 [*]	.59217	.004	.6321	3.0257	
			Control/RP	.04333	.59217	.942	-1.1535	1.2402	
			Control	RS	-.56556	.59217	.345	-1.7624	.6313
			RS	-.97889	.59217	.106	-2.1757	.2179	
		Control	RS/RK	1.78556 [*]	.59217	.004	.5887	2.9824	
			RS/ISD	-.04333	.59217	.942	-1.2402	1.1535	
			RS	-.86556	.33622	.095	-1.8258	.0947	
			RS/RK	-.14889	.33622	.992	-1.1092	.8114	
		RS	RS/ISD	5.95000 [†]	.33622	.000	4.9897	6.9103	
			Control/RP	4.28333 [†]	.33622	.000	3.3231	5.2436	
			Control	RS	.86556	.33622	.095	-.0947	1.8258
			RS/RK	.71667	.33622	.227	-.2436	1.6769	
		RS/RK	RS/ISD	6.81556 [†]	.33622	.000	5.8553	7.7758	
			Control/RP	5.14889 [†]	.33622	.000	4.1886	6.1092	
			Control	RS	.14889	.33622	.992	-.8114	1.1092
			RS	-.71667	.33622	.227	-1.6769	.2436	
		RS/ISD	RS/ISD	6.09889 [†]	.33622	.000	5.1386	7.0592	
			Control/RP	4.43222 [†]	.33622	.000	3.4719	5.3925	
			Control	RS	-5.95000 [†]	.33622	.000	-6.9103	-4.9897
			RS	-6.81556 [†]	.33622	.000	-7.7758	-5.8553	
		Control/RP	RS/RK	-6.09889 [†]	.33622	.000	-7.0592	-5.1386	
			Control/RP	-1.66667 [†]	.33622	.000	-2.6269	-.7064	
			Control	RS	-4.28333 [†]	.33622	.000	-5.2436	-3.3231
			RS	-5.14889 [†]	.33622	.000	-6.1092	-4.1886	
		LSD	RS/RK	-4.43222 [†]	.33622	.000	-5.3925	-3.4719	
			RS/ISD	1.66667 [†]	.33622	.000	.7064	2.6269	
			Control	RS	-.86556 [*]	.33622	.014	-1.5451	-.1860
			RS/RK	-.14889	.33622	.660	-.8284	.5306	
RS	RS/ISD	5.95000 [†]	.33622	.000	5.2705	6.6295			
	Control/RP	4.28333 [†]	.33622	.000	3.6038	4.9629			
	Control	RS	.86556 [*]	.33622	.014	.1860	1.5451		
	RS/RK	.71667 [*]	.33622	.039	.0371	1.3962			
Control	RS/ISD	6.81556 [†]	.33622	.000	6.1360	7.4951			
	Control/RP	5.14889 [†]	.33622	.000	4.4694	5.8284			

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
	RS/RK	Control	.14889	.33622	.660	-.5306	.8284
		RS	-.71667*	.33622	.039	-1.3962	-.0371
		RS/ISD	6.09889*	.33622	.000	5.4194	6.7784
		Control/RP	4.43222*	.33622	.000	3.7527	5.1118
	RS/ISD	Control	-5.95000*	.33622	.000	-6.6295	-5.2705
		RS	-6.81556*	.33622	.000	-7.4951	-6.1360
		RS/RK	-6.09889*	.33622	.000	-6.7784	-5.4194
		Control/RP	-1.66667*	.33622	.000	-2.3462	-.9871
	Control/RP	Control	-4.28333*	.33622	.000	-4.9629	-3.6038
		RS	-5.14889*	.33622	.000	-5.8284	-4.4694
		RS/RK	-4.43222*	.33622	.000	-5.1118	-3.7527
		RS/ISD	1.66667*	.33622	.000	.9871	2.3462

*. The mean difference is significant at the 0.05 level.

Crustcolour_L_Bread

		Subset for alpha = 0.05				
Bread		N	1	2	3	4
Tukey HSD ^a	RS/ISD	9	46.6522			
	Control/RP	9		50.5789		
	Control	9			51.8200	
	RS	9				56.9944
	RS/RK	9				57.6689
	Sig.			1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Crustcolour_a_Bread

		Subset for alpha = 0.05		
Bread		N	1	2
Tukey HSD ^a	RS/RK	9	7.7333	
	Control/RP	9		9.5189
	RS/ISD	9		9.5622
	Control	9		10.0844
	RS	9		10.4978
Sig.			1.000	.474

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

Crustcolour_b_Bread

		Subset for alpha = 0.05			
Bread		N	1	2	3
Tukey HSD ^a	RS/ISD	9	20.3133		
	Control/RP	9		21.9800	
	Control	9			26.2633
	RS/RK	9			26.4122
	RS	9			27.1289
Sig.			1.000	1.000	.095

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 9.000.

D.13 Statistical analysis of mean sensory attribute scores of baked GF sweet potato sourdough breads made using different formulations and fermentation processes

		Descriptives							
		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
						Lower Bound	Upper Bound		
Sensory_Appearance_Bread	Control	50	6.8700	1.10107	.15571	6.5571	7.1829	3.00	9.00
	RS	50	6.9400	1.21907	.17240	6.5935	7.2865	4.00	9.00
	RS/RK	50	6.7900	1.28607	.18188	6.4245	7.1555	4.00	9.00
	RS/ISD	50	6.5000	1.28174	.18127	6.1357	6.8643	4.00	9.00
	Control/RP	50	7.0200	1.16916	.16534	6.6877	7.3523	3.00	9.00
	Total	250	6.8240	1.21694	.07697	6.6724	6.9756	3.00	9.00
Sensory_Texture_Bread	Control	50	6.5100	.98193	.13887	6.2309	6.7891	4.00	9.00
	RS	50	6.7100	1.34805	.19064	6.3269	7.0931	1.00	9.00
	RS/RK	50	6.0200	1.59706	.22586	5.5661	6.4739	3.00	9.00
	RS/ISD	50	6.1900	1.58723	.22447	5.7389	6.6411	3.00	9.00
	Control/RP	50	7.4800	.81416	.11514	7.2486	7.7114	5.00	9.00
	Total	250	6.5820	1.39141	.08800	6.4087	6.7553	1.00	9.00
Sensory_Aroma_Bread	Control	50	5.7300	1.36729	.19336	5.3414	6.1186	3.00	8.00
	RS	50	5.5400	1.29694	.18341	5.1714	5.9086	3.00	9.00
	RS/RK	50	5.4600	1.32803	.18781	5.0826	5.8374	2.00	8.00
	RS/ISD	50	5.6300	1.24871	.17659	5.2751	5.9849	3.00	9.00
	Control/RP	50	6.4400	1.26829	.17936	6.0796	6.8004	3.00	9.00
	Total	250	5.7600	1.33924	.08470	5.5932	5.9268	2.00	9.00
Sensory_Taste_Bread	Control	50	6.4800	1.23288	.17436	6.1296	6.8304	3.00	9.00
	RS	50	6.0200	1.58423	.22404	5.5698	6.4702	3.00	9.00
	RS/RK	50	5.7000	1.43214	.20253	5.2930	6.1070	3.00	9.00
	RS/ISD	50	5.6800	1.53117	.21654	5.2448	6.1152	2.00	8.00
	Control/RP	50	7.6400	.82709	.11697	7.4049	7.8751	5.00	9.00
	Total	250	6.3040	1.52476	.09643	6.1141	6.4939	2.00	9.00
Sensory_Overallacceptability_Bread	Control	50	6.5900	1.02862	.14547	6.2977	6.8823	4.00	9.00
	RS	50	6.2700	1.23392	.17450	5.9193	6.6207	3.00	9.00
	RS/RK	50	5.7700	1.35228	.19124	5.3857	6.1543	3.00	8.00
	RS/ISD	50	5.7400	1.37113	.19391	5.3503	6.1297	2.00	8.00
	Control/RP	50	7.4800	.76238	.10782	7.2633	7.6967	5.00	9.00
	Total	250	6.3700	1.32784	.08398	6.2046	6.5354	2.00	9.00

		ANOVA				
		Sum of Squares	df	Mean Square	F	Sig.
Sensory_Appearance_Bread	Between Groups	8.006	4	2.001	1.359	.249
	Within Groups	360.750	245	1.472		
	Total	368.756	249			
Sensory_Texture_Bread	Between Groups	64.874	4	16.219	9.524	.000
	Within Groups	417.195	245	1.703		
	Total	482.069	249			
Sensory_Aroma_Bread	Between Groups	30.930	4	7.733	4.558	.001
	Within Groups	415.670	245	1.697		
	Total	446.600	249			
Sensory_Taste_Bread	Between Groups	132.536	4	33.134	18.187	.000
	Within Groups	446.360	245	1.822		
	Total	578.896	249			
Sensory_Overallacceptability_Bread	Between Groups	102.370	4	25.593	18.625	.000
	Within Groups	336.655	245	1.374		
	Total	439.025	249			

Sensory_Appearance_Bread

		Subset for alpha = 0.05	
Bread	N	1	
Tukey HSD ^a	RS/ISD	50	6.5000
	RS/RK	50	6.7900
	Control	50	6.8700
	RS	50	6.9400
	Control/RP	50	7.0200
	Sig.		.206

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 50.000.

Sensory_Texture_Bread

		Subset for alpha = 0.05		
Bread	N	1	2	
Tukey HSD ^a	RS/RK	50	6.0200	
	RS/ISD	50	6.1900	
	Control	50	6.5100	
	RS	50	6.7100	
	Control/RP	50		7.4800
	Sig.		.066	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 50.000.

Sensory_Aroma_Bread

		Subset for alpha = 0.05		
Bread	N	1	2	
Tukey HSD ^a	RS/RK	50	5.4600	
	RS	50	5.5400	
	RS/ISD	50	5.6300	
	Control	50	5.7300	5.7300
	Control/RP	50		6.4400
	Sig.		.838	.053

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 50.000.

Sensory_Taste_Bread

		Subset for alpha = 0.05			
Bread	N	1	2	3	
Tukey HSD ^a	RS/ISD	50	5.6800		
	RS/RK	50	5.7000		
	RS	50	6.0200	6.0200	
	Control	50		6.4800	
	Control/RP	50			7.6400
	Sig.		.716	.433	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 50.000.

Sensory_Overallacceptability_Bread

		Subset for alpha = 0.05			
Bread	N	1	2	3	
Tukey HSD ^a	RS/ISD	50	5.7400		
	RS/RK	50	5.7700		
	RS	50	6.2700	6.2700	
	Control	50		6.5900	
	Control/RP	50			7.4800
	Sig.		.161	.651	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 50.000.

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Sensory_Appearance_Bread	Tukey HSD	Control	RS	-.07000	.24269	.998	-.7370	.5970
			RS/RK	.08000	.24269	.997	-.5870	.7470
			RS/ISD	.37000	.24269	.547	-.2970	1.0370
			Control/RP	-.15000	.24269	.972	-.8170	.5170
		RS	Control	.07000	.24269	.998	-.5970	.7370
			RS/RK	.15000	.24269	.972	-.5170	.8170
			RS/ISD	.44000	.24269	.368	-.2270	1.1070
			Control/RP	-.08000	.24269	.997	-.7470	.5870
		RS/RK	Control	-.08000	.24269	.997	-.7470	.5870
			RS	-.15000	.24269	.972	-.8170	.5170
			RS/ISD	.29000	.24269	.754	-.3770	.9570
			Control/RP	-.23000	.24269	.878	-.8970	.4370
	RS/ISD	Control	-.37000	.24269	.547	-1.0370	.2970	
		RS	-.44000	.24269	.368	-1.1070	.2270	
		RS/RK	-.29000	.24269	.754	-.9570	.3770	
		Control/RP	-.52000	.24269	.206	-1.1870	.1470	
	Control/RP	Control	.15000	.24269	.972	-.5170	.8170	
		RS	.08000	.24269	.997	-.5870	.7470	
		RS/RK	.23000	.24269	.878	-.4370	.8970	
		RS/ISD	.52000	.24269	.206	-.1470	1.1870	
	LSD	Control	RS	-.07000	.24269	.773	-.5480	.4080
			RS/RK	.08000	.24269	.742	-.3980	.5580
			RS/ISD	.37000	.24269	.129	-.1080	.8480
			Control/RP	-.15000	.24269	.537	-.6280	.3280
		RS	Control	.07000	.24269	.773	-.4080	.5480
			RS/RK	.15000	.24269	.537	-.3280	.6280
			RS/ISD	.44000	.24269	.071	-.0380	.9180
			Control/RP	-.08000	.24269	.742	-.5580	.3980
		RS/RK	Control	-.08000	.24269	.742	-.5580	.3980
			RS	-.15000	.24269	.537	-.6280	.3280
			RS/ISD	.29000	.24269	.233	-.1880	.7680
			Control/RP	-.23000	.24269	.344	-.7080	.2480
	RS/ISD	Control	-.37000	.24269	.129	-.8480	.1080	
		RS	-.44000	.24269	.071	-.9180	.0380	
		RS/RK	-.29000	.24269	.233	-.7680	.1880	
		Control/RP	-.52000	.24269	.033	-.9980	-.0420	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
Sensory_Texture_Bread	Control/RP	Control	.15000	.24269	.537	-.3280	.6280		
		RS	.08000	.24269	.742	-.3980	.5580		
		RS/RK	.23000	.24269	.344	-.2480	.7080		
		RS/ISD	.52000*	.24269	.033	.0420	.9980		
	Tukey HSD	Control	RS	-.20000	.26099	.940	-.9172	.5172	
			RS/RK	.49000	.26099	.332	-.2272	1.2072	
			RS/ISD	.32000	.26099	.736	-.3972	1.0372	
			Control/RP	-.97000*	.26099	.002	-1.6872	-.2528	
		RS	Control	.20000	.26099	.940	-.5172	.9172	
			RS/RK	.69000	.26099	.066	-.0272	1.4072	
			RS/ISD	.52000	.26099	.273	-.1972	1.2372	
			Control/RP	-.77000*	.26099	.028	-1.4872	-.0528	
		RS/RK	Control	-.49000	.26099	.332	-1.2072	.2272	
			RS	-.69000	.26099	.066	-1.4072	.0272	
			RS/ISD	-.17000	.26099	.966	-.8872	.5472	
			Control/RP	-1.46000*	.26099	.000	-2.1772	-.7428	
		RS/ISD	Control	-.32000	.26099	.736	-1.0372	.3972	
			RS	-.52000	.26099	.273	-1.2372	.1972	
			RS/RK	.17000	.26099	.966	-.5472	.8872	
			Control/RP	-1.29000*	.26099	.000	-2.0072	-.5728	
		Control/RP	Control	.97000*	.26099	.002	.2528	1.6872	
			RS	.77000*	.26099	.028	.0528	1.4872	
			RS/RK	1.46000*	.26099	.000	.7428	2.1772	
			RS/ISD	1.29000*	.26099	.000	.5728	2.0072	
		LSD	Control	RS	-.20000	.26099	.444	-.7141	.3141
				RS/RK	.49000	.26099	.062	-.0241	1.0041
				RS/ISD	.32000	.26099	.221	-.1941	.8341
				Control/RP	-.97000*	.26099	.000	-1.4841	-.4659
			RS	Control	.20000	.26099	.444	-.3141	.7141
				RS/RK	.69000*	.26099	.009	.1759	1.2041
				RS/ISD	.52000*	.26099	.047	.0059	1.0341
				Control/RP	-.77000*	.26099	.003	-1.2841	-.2559
			RS/RK	Control	-.49000	.26099	.062	-1.0041	.0241
				RS	-.69000*	.26099	.009	-1.2041	-.1759
				RS/ISD	-.17000	.26099	.515	-.6841	.3441
				Control/RP	-1.46000*	.26099	.000	-1.9741	-.9459
			RS/ISD	Control	-.32000	.26099	.221	-.8341	.1941
				RS	-.52000*	.26099	.047	-1.0341	-.0059
				RS/RK	.17000	.26099	.515	-.3441	.6841
				Control/RP	-1.29000*	.26099	.000	-1.8041	-.7759
Control/RP			Control	.97000*	.26099	.000	.4559	1.4841	
			RS	.77000*	.26099	.003	.2559	1.2841	
			RS/RK	1.46000*	.26099	.000	.9459	1.9741	
			RS/ISD	1.29000*	.26099	.000	.7759	1.8041	
Sensory_Aroma_Bread	Tukey HSD		Control	RS	.19000	.26051	.950	-.5259	.9059
				RS/RK	.27000	.26051	.838	-.4459	.9859
				RS/ISD	.10000	.26051	.995	-.6159	.8159
				Control/RP	-.71000	.26051	.053	-1.4259	.0059
	RS		Control	-.19000	.26051	.950	-.9059	.5259	
			RS/RK	.08000	.26051	.998	-.6359	.7959	
			RS/ISD	-.09000	.26051	.997	-.8059	.6259	
			Control/RP	-.90000*	.26051	.006	-1.6159	-.1841	
	RS/RK		Control	-.27000	.26051	.838	-.9859	.4459	
			RS	-.08000	.26051	.998	-.7959	.6359	
			RS/ISD	-.17000	.26051	.966	-.8859	.5459	
			Control/RP	-.98000*	.26051	.002	-1.6959	-.2641	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval			
						Lower Bound	Upper Bound		
	RS/ISD	Control	-.10000	.26051	.995	-.8159	.6159		
		RS	.09000	.26051	.997	-.6259	.8059		
		RS/RK	.17000	.26051	.966	-.5459	.8859		
		Control/RP	-.81000*	.26051	.018	-1.5259	-.0941		
	Control/RP	Control	.71000	.26051	.053	-.0059	1.4259		
		RS	.90000*	.26051	.006	.1841	1.6159		
		RS/RK	.98000*	.26051	.002	.2641	1.6959		
		RS/ISD	.81000*	.26051	.018	.0941	1.5259		
	LSD	Control	RS	.19000	.26051	.466	-.3231	.7031	
			RS/RK	.27000	.26051	.301	-.2431	.7831	
			RS/ISD	.10000	.26051	.701	-.4131	.6131	
			Control/RP	-.71000*	.26051	.007	-1.2231	-.1969	
		RS	Control	-.19000	.26051	.466	-.7031	.3231	
			RS/RK	.08000	.26051	.759	-.4331	.5931	
			RS/ISD	-.09000	.26051	.730	-.6031	.4231	
			Control/RP	-.90000*	.26051	.001	-1.4131	-.3869	
		RS/RK	Control	-.27000	.26051	.301	-.7831	.2431	
			RS	-.08000	.26051	.759	-.5931	.4331	
			RS/ISD	-.17000	.26051	.515	-.6831	.3431	
			Control/RP	-.98000*	.26051	.000	-1.4931	-.4669	
	RS/ISD	Control	-.10000	.26051	.701	-.6131	.4131		
		RS	.09000	.26051	.730	-.4231	.6031		
		RS/RK	.17000	.26051	.515	-.3431	.6831		
		Control/RP	-.81000*	.26051	.002	-1.3231	-.2969		
	Control/RP	Control	.71000*	.26051	.007	.1969	1.2231		
		RS	.90000*	.26051	.001	.3869	1.4131		
		RS/RK	.98000*	.26051	.000	.4669	1.4931		
		RS/ISD	.81000*	.26051	.002	.2969	1.3231		
	Sensory_Taste_Bread	Tukey HSD	Control	RS	.46000	.26995	.433	-.2819	1.2019
				RS/RK	.78000*	.26995	.034	.0381	1.5219
				RS/ISD	.80000*	.26995	.027	.0581	1.5419
				Control/RP	-1.16000*	.26995	.000	-1.9019	-.4181
			RS	Control	-.46000	.26995	.433	-1.2019	.2819
				RS/RK	.32000	.26995	.760	-.4219	1.0619
				RS/ISD	.34000	.26995	.716	-.4019	1.0819
				Control/RP	-1.62000*	.26995	.000	-2.3619	-.8781
			RS/RK	Control	-.78000*	.26995	.034	-1.5219	-.0381
				RS	-.32000	.26995	.760	-1.0619	.4219
				RS/ISD	.02000	.26995	1.000	-.7219	.7619
				Control/RP	-1.94000*	.26995	.000	-2.6819	-1.1981
RS/ISD		Control	-.80000*	.26995	.027	-1.5419	-.0581		
		RS	-.34000	.26995	.716	-1.0819	.4019		
		RS/RK	-.02000	.26995	1.000	-.7619	.7219		
		Control/RP	-1.96000*	.26995	.000	-2.7019	-1.2181		
Control/RP		Control	1.16000*	.26995	.000	.4181	1.9019		
		RS	1.62000*	.26995	.000	.8781	2.3619		
		RS/RK	1.94000*	.26995	.000	1.1981	2.6819		
		RS/ISD	1.96000*	.26995	.000	1.2181	2.7019		
LSD		Control	RS	.46000	.26995	.090	-.0717	.9917	
			RS/RK	.78000*	.26995	.004	.2483	1.3117	
			RS/ISD	.80000*	.26995	.003	.2683	1.3317	
			Control/RP	-1.16000*	.26995	.000	-1.6917	-.6283	
		RS	Control	-.46000	.26995	.090	-.9917	.0717	
			RS/RK	.32000	.26995	.237	-.2117	.8517	
			RS/ISD	.34000	.26995	.209	-.1917	.8717	
			Control/RP	-1.62000*	.26995	.000	-2.1517	-1.0883	

Multiple Comparisons

Dependent Variable	(I) Bread	(J) Bread	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval		
						Lower Bound	Upper Bound	
Sensory_Overallacceptability_Bread	RS/RK	Control	-.78000*	.26995	.004	-1.3117	-.2483	
		RS	-.32000	.26995	.237	-.8517	.2117	
		RS/ISD	.02000	.26995	.941	-.5117	.5517	
		Control/RP	-1.94000*	.26995	.000	-2.4717	-1.4083	
	RS/ISD	Control	-.80000*	.26995	.003	-1.3317	-.2683	
		RS	-.34000	.26995	.209	-.8717	.1917	
		RS/RK	-.02000	.26995	.941	-.5517	.5117	
		Control/RP	-1.96000*	.26995	.000	-2.4917	-1.4283	
	Control/RP	Control	1.16000*	.26995	.000	.6283	1.6917	
		RS	1.62000*	.26995	.000	1.0883	2.1517	
		RS/RK	1.94000*	.26995	.000	1.4083	2.4717	
		RS/ISD	1.96000*	.26995	.000	1.4283	2.4917	
	LSD	Control	RS	.32000	.23444	.651	-.3243	.9643
			RS/RK	.82000*	.23444	.005	.1757	1.4643
			RS/ISD	.85000*	.23444	.003	.2057	1.4943
			Control/RP	-.89000*	.23444	.002	-1.5343	-.2457
RS		Control	-.32000	.23444	.651	-.9643	.3243	
		RS/RK	.50000	.23444	.210	-.1443	1.1443	
		RS/ISD	.53000	.23444	.161	-.1143	1.1743	
		Control/RP	-1.21000*	.23444	.000	-1.8543	-.5657	
RS/RK		Control	-.82000*	.23444	.005	-1.4643	-.1757	
		RS	-.50000	.23444	.210	-1.1443	.1443	
		RS/ISD	.03000	.23444	1.000	-.6143	.6743	
		Control/RP	-1.71000*	.23444	.000	-2.3543	-1.0657	
RS/ISD		Control	-.85000*	.23444	.003	-1.4943	-.2057	
		RS	-.53000	.23444	.161	-1.1743	.1143	
		RS/RK	-.03000	.23444	1.000	-.6743	.6143	
		Control/RP	-1.74000*	.23444	.000	-2.3843	-1.0957	
Control/RP		Control	.89000*	.23444	.002	.2457	1.5343	
		RS	1.21000*	.23444	.000	.5657	1.8543	
		RS/RK	1.71000*	.23444	.000	1.0657	2.3543	
		RS/ISD	1.74000*	.23444	.000	1.0957	2.3843	
Control	RS	.32000	.23444	.174	-.1418	.7818		
	RS/RK	.82000*	.23444	.001	.3582	1.2818		
	RS/ISD	.85000*	.23444	.000	.3882	1.3118		
	Control/RP	-.89000*	.23444	.000	-1.3518	-.4282		
RS	Control	-.32000	.23444	.174	-.7818	.1418		
	RS/RK	.50000*	.23444	.034	.0382	.9618		
	RS/ISD	.53000*	.23444	.025	.0682	.9918		
	Control/RP	-1.21000*	.23444	.000	-1.6718	-.7482		
RS/RK	Control	-.82000*	.23444	.001	-1.2818	-.3582		
	RS	-.50000*	.23444	.034	-.9618	-.0382		
	RS/ISD	.03000	.23444	.898	-.4318	.4918		
	Control/RP	-1.71000*	.23444	.000	-2.1718	-1.2482		
RS/ISD	Control	-.85000*	.23444	.000	-1.3118	-.3882		
	RS	-.53000*	.23444	.025	-.9918	-.0682		
	RS/RK	-.03000	.23444	.898	-.4918	.4318		
	Control/RP	-1.74000*	.23444	.000	-2.2018	-1.2782		
Control/RP	Control	.89000*	.23444	.000	.4282	1.3518		
	RS	1.21000*	.23444	.000	.7482	1.6718		
	RS/RK	1.71000*	.23444	.000	1.2482	2.1718		
	RS/ISD	1.74000*	.23444	.000	1.2782	2.2018		

*. The mean difference is significant at the 0.05 level.