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Third generation extruded snacks with ancient grains

A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
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ABSTRACT

Third generation (3G) is a term that refers to the levels of processing used to produce a finished product. A 3G snack product starts with a starch based recipe that is extrusion cooked, formed into a dense shaped pellet and then dried. At this point, it is referred to as semi or half product because it needs to be further puffed to develop its texture and flavour. The objective of this project was to develop an unflavoured cereal-based 3G snack formulation with ancient grains. The snack must be unique in shape and suitable for hot air-puffing.

Two 3G wholegrain base formulations were developed. One formulation was made from coarse rice flour, wholemeal wheat flour, potato starch, ancient grain blend (one third amaranth, one third quinoa and one third millet), wheat fibre 600 and salt. The second formulation was maize based by replacing coarse rice flour with maize polenta. These two base formulations contained ancient grains and nutrients that provide health benefits and were suitable for air-puffing. A lab-scale model Cleextral BC21 twin screw co-rotating extruder was used for this study. Pasting properties of samples were evaluated using the Rapid Visco Analyser. It was found that ingredient selection and extrusion processing affected extruded pellets' paste viscosities, the die swell and product expansion.

Pasting properties of raw ingredient blend were affected by amylose and lipid content, and particle size of the cereal flour. The more even the raw material particle size was, the more even was the hydration of the material in the extruder. The results showed that inclusion of dietary fibre (wheat fibre 600, Beneo GR or Hi-Maize™ 1043) in the 3G formulations decreased raw ingredients' and extruded pellets' paste viscosities, which resulted in reduced pellet expansion. It was found that wheat fibre 600 at 4 % was the best fibre choice to produce a 3G snack, because it accelerated extruded pellet drying, helped in 'pellet checking' control and producing more uniform cell sized expanded products. Hi-Maize™ ingredients were found to lead to the deterioration of viscosity and snack pellet expansion, and therefore not recommended to be used for 3G snack base formulation.

Increasing the water injection rate to the extruder (from 1.0 to 1.7 L/h) decreased the extruder apparent torque, thrust pressure, die pressure and SME. The degree of starch degradation was also reduced, but the product expansion was increased. Pellet expansion was found closely correlated to the pasting properties of the raw ingredient blend. Pellet expansion increased with the increase of peak viscosity (PV) and final viscosity (FV) of the raw ingredient blend.

A suitable laboratory drying method was developed for 3G snacks. It was found that drying and holding at 1 h ± 5 min intervals including a pre-drying step had minimal pellets defects. Humidity control (60 %) was required throughout this drying process. After puffing, the product sectional expansion index (SEI) increased with the increase in salt concentration from 0.5 % to 1.0 % and increase in moisture content from 9.5 % to 12.1 %. The extruded pellets moisture was found to have the most significant effect on

the finished product expansion, and maximum expansion due to puffing was found at 10.6 % pellet moisture.

A shear-compression analysis of the 3G product prototypes and competitor products showed that most of low moisture commercial snack products available in the market have low bulk density and were brittle. The products produced from the proposed 3G formulations were much harder than the commercial products.

Qualitative consumer focus group studies were conducted to gain insights into consumers' attitudes towards extruded snacks, desirable texture and product claims to be included in the product. The results showed that five themes typically associated with snack consumption (nostalgia, special social occasions, distraction, convenient treat and hunger). Taste and price were the most important to the participants, and the health benefits were only an extra bonus. Participants were not tempted by an ancient grain claim. Product prototypes did not receive very positive feedback due to the taste and the product size. Product texture was found acceptable by most participants.

This study produced initial formulations for a 3G snack, provided a good starting point for understanding of the 3G extruded snack process and provided valuable information for further development work. Further work is required to scale up the recipe, to increase the snack size, to further improve of the 3G snack flavour without significantly increasing the salt content and to carry out a consumer acceptance study on the scaled up 3G snack products.

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LIST OF NOMENCLATURES

Ancient grains generally refer to a group of cereal grains or pseudo-cereals that are largely unchanged over the last several hundred years. The most common ancient grains are native to South America including amaranth, quinoa, barley, chia, buckwheat, kamut®, sorghum, millet, spelt and teff.

Beneo GR is a water soluble dietary fibre consisting mainly of chicory inulin, GR stands for granulated powder (details can be found in Appendix A 1.4).

Beneo Hi is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Beneo GR (4 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

Beneo Lo is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Beneo GR (2 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

Breakdown (BD) is the peak viscosity minus the viscosity after the holding period at 95 °C in a RVA analysis.

Carbohydrate by difference is calculated by subtracting from 100, the average quantity expressed as a percentage of water, protein, fat, dietary fibre, ash, alcohol, and any other unavailable carbohydrate (FSANZ Standard 1.2.8).

Cold Peak (CP) is the maximum cold water viscosity observed at 25 °C in a RVA analysis.

CW is a 3G base formulation made from maize polenta, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt (0.5 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

CW Water Hi is the 3G base formulation 'CW' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 88.

CW Water Lo is the 3G base formulation 'CW' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water addition rate 1.0 kg/h and feed rate dial 70.

CW Salt Hi is a 3G base formulation made from maize polenta, wholemeal wheat flour (30 %), potato starch, ancient grain blend and salt (1 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

Die conductance measures the magnitude of the resistance to flow. The die conductance (k) is a function of die geometry and material of construction.

Die swell is the overall expansion of a pellet. It was calculated by dividing the dimension of the pellet by dimension of the die opening.

Flavex is a vegetable protein extract produced by the acid hydrolysis of vegetable proteins. It has an intense savoury flavour and has been used as a flavour enhancer (details can be found in section A 1.5 of Appendix 1).

Hi-Maize™ 1043 is a natural, unmodified, high amylose resistant starch made from maize (details can be found in Appendix A 1.4).

Hi-Maize Hi is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Hi-Maize™ 1043 (7 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

Hi-Maize Lo is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Hi-Maize™ 1043 (3.5 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

Nut brown flour is a light to medium brown finely grounded wholegrain meal with negligible diastatic activity. It is produced by milling crystal malted barley. It has pleasant roasted aroma and slightly bitter sweet in taste (details can be found in section A1.5 of Appendix 1).

Pasting temp is the temperature in a RVA analysis where viscosity first increases by at least 25 cP over a 20 s period. It provides an indication of the minimum temperature required to cook a given sample.

Peak viscosity (PV) is the maximum paste viscosity achieved during the heating cycle of a RVA analysis;

Peak time (PT) is time when maximum paste viscosity achieved in a RVA analysis;

Pellet checking is the hairline crack on or under the surface of the pellets. The formation of checking is pellet cannot deform enough to relax stresses causing by pellet drying before entering the glassy state. Pellet shrinks on losing moisture and the dry outside region will try to contract onto the wet core. Hence the outside of the pellet will be under tension and the core under compression. Checking can occur either during the drying cycle or as long as several weeks after the product has been packaged.

RW is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt (0.5 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

RW Water Hi (WF Hi) is the 3G base formulation 'RW' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

RW Water Lo is the 3G base formulation 'RW' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water addition rate 1.0 kg/h and feed rate dial 60.

RW Salt Hi is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (30 %), potato starch, ancient grain blend and salt (1 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

RWC is a 3G base formulation made from coarse rice flour, potato starch, wholemeal wheat flour (21 %), Hi-Maize wholegrain flour (10 %), ancient grain blend, white sugar, nut brown flour and salt (0.5 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

RWC Water Hi is the 3G base formulation 'RWC' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 85.

RWC Water Lo is the 3G base formulation 'RWC' extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water addition rate 1.0 kg/h and feed rate dial 70.

RWC Salt Hi is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (20 %), potato starch, Hi-Maize wholegrain flour (10 %), ancient grain blend and salt (1 %). Wheat fibre 600 (4 %) was added to the 3G base formulation.

Salt Hi is a 3G base formulation made from maize polenta, wholemeal wheat flour (30 %), potato starch, ancient grain blend and salt (1.0 %). Wheat fibre 600 (4 %) was added to the 3G base

formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at extruder screw speed 251 rpm, water rate 1.0 kg/h and the feed rate dial 75.

Salt Hi&Flavex is a 3G base formulation made from maize polenta, wholemeal wheat flour (30 %), potato starch, ancient grain blend, salt (1.0 %) and Flavex (0.3 %). Wheat fibre 600 (4 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at extruder screw speed 251 rpm, water rate 1.0 kg/h and the feed rate dial 80.

Salt Lo is a 3G base formulation made from maize polenta, wholemeal wheat flour (30 %), potato starch, ancient grain blend and salt (0.5 %). Wheat fibre 600 (4 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at extruder screw speed 251 rpm, water rate 1.0 kg/h and the feed rate dial 75.

Salt Lo&Flavex is a 3G base formulation made from maize polenta, wholemeal wheat flour (30 %), potato starch, ancient grain blend, salt (0.5 %) and Flavex (0.3 %). Wheat fibre 600 (4 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at extruder screw speed 251 rpm, water rate 1.0 kg/h and the feed rate dial 75.

Setback (SB) is difference between the final viscosity and the viscosity reached after the first holding period in a RVA analysis.

Starch dextrinisation is a process known as a certain degree of fragmentation during extrusion cooking, a decrease in high molecular weight material and a corresponding increase in lower molecular weight polysaccharide.

WF Hi (RW Water Hi) is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Wheat fibre 600 (4 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

WF Lo is a 3G base formulation made from coarse rice flour, wholemeal wheat flour (31 %), potato starch, ancient grain blend, white sugar, nut brown flour and salt. Wheat fibre 600 (2 %) was added to the 3G base formulation and extruded using a Cleextral BC21 twin screw co-rotating extruder (Firminy Cedex, France) at screw speed 251 rpm, water rate 1.7 kg/h and feed rate dial 60.

Wheat Fibre 600 is a creamy white, microfine water insoluble dietary fibre produced by a special process from the structure building components of the wheat plant according to the supplier specification (details can be found in Appendix A 1.4).