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# **Preparation and Characterisation of Avocado Cream Cheeses: Effects of Different Treatments and Ratios of Avocado Puree**

**A thesis presented in partial fulfilment of the requirements  
for the degree of Master of Food Technology  
at Massey University, Auckland, New Zealand**

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## **Abstract**

Cream cheese fortified with the addition of avocado puree to improve its nutritional value has not been developed in the food industry, although some studies have researched the possibility of mixing cream cheese products with other fruits. This research study initially aimed to develop a novel cream cheese fortified with avocado puree by finding the appropriate concentration level and a proper processing condition to preserve avocado puree from colour degradation. Four levels of avocado puree (0, 10, 20 and 30%) were investigated in this research to figure out the effect of avocado puree concentrations on cream cheese quality and stability during 28-day storage to select one proper avocado concentration. Then, three different treatments of avocado puree were used for preserving avocado puree in this research, such as i) addition of ascorbic acid, ii) use of high-pressure processing (HPP), and iii) a combination of HPP and ascorbic acid, to investigate whether these treatments had any effects on the avocado puree fortified cream cheese quality and stability during the storage at 4°C for 4 weeks. This research characterised several essential properties of cream cheese, including textural properties, colour stability, microbiological safety, rheological properties, and microstructure. This research aimed to determine the impacts of avocado puree and treated avocado puree on cream cheese's formation, properties, and stability. The cream cheese samples prepared in this research were analysed weekly after preparation and during storage. After researching these basic cream cheese properties, a comprehensive sensory evaluation was conducted to determine consumers preferred avocado puree concentration and processing condition.

The results revealed that adding 20% (w/w) of avocado puree in cream cheese and treating it with HPP with the addition of ascorbic acid was the most suitable approach to developing an avocado-fortified cream cheese with desired sensory properties and stability. All physicochemical properties of avocado-fortified cream cheese produced in this research appeared to be significantly affected by avocado levels, especially at 30% concentration, and the different methods of treatment applied to avocado puree had a slight impact on the

cream cheese's properties compared to the control sample (cream cheese with untreated avocado puree, i.e. without HPP and ascorbic acid). As mentioned above, the most appropriate avocado puree concentration in cream cheese was 20% in this study. To be specific, cream cheese added with 20% avocado puree showed relatively stable textural and rheological properties during storage for 4 weeks at 4°C. The sensory evaluation results showed that participants preferred cream cheese containing 20% avocado puree among the four levels of avocado puree (0, 10, 20 and 30%). As for the effects of avocado puree's processing conditions, adding ascorbic acid as an additive in HPP-treated avocado puree was found to contribute better to lowering colour changes and syneresis in cream cheese samples. This treatment also showed a relatively small impact on changes in the cream cheese's textural properties and the flow behaviour during storage at 4°C compared to other treatments. Also, it helped cream cheese containing avocado puree only had a slight change in colour with the total colour change ( $\Delta E$ ) value of 1.31 and less syneresis (2.63%) after the storage period compared to the other samples. Besides, more than 50% of participants had positive opinions on this sample from sensory evaluation. However, this project did not research other possible concentrations of avocado puree and their treatments, such as adding other kinds of antioxidants, chelating agent and hydrocolloids. These other variables are recommended to investigate for further development. This project provides vital insight into developing a novel avocado-fortified cream cheese and suitable processing to protect avocado puree from degradation in cream cheese during storage.

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# Chapter 1. Introduction

## 1.1 Background

Cheese is a fermented dairy product that plays an increasingly important role in the dairy industry, and the global cheese market is predicted to increase to about 8.3 billion U.S. dollars before 2026 (Pombo, 2020). The versatility of cheese-related products provides numerous applications in the food industry. This is because cheese products have a matrix that can be incorporated with various types of flavours, herbs, fruits and condiments (Guinee & Hickey, 2009). One example is a cream cheese's application in making a New York-style cheesecake with different flavours, which is different to the traditional cheesecake (Pombo, 2020).

Cream cheese is an unripened cheese produced by coagulating milk proteins with acid via the fermentation of milk with fresh cream using lactic acid bacteria for acidification. This acid-coagulated cheese product has a slightly sour taste and buttery flavour with a spreadable creamy texture with a shiny appearance. According to the USDA (1994), cream cheese has at least 33% fat and less than 55% moisture content. However, some low-fat cream cheese products can contain less fat content from the range of 0.5% to 16.5% and a maximum moisture content of 70% (Lucey, 2011). Cream cheese is a versatile cheese product that can be consumed as a spread, dip or butter replacer or used to make some food products, such as desserts and baked foods. However, cream cheese products available in the market have a relatively high saturated fat and sodium (Rinaldoni et al., 2014). Thus, developing a new cream cheese product with health benefits, such as less saturated fat, more unsaturated fat, low sodium and sugar and lactose-free, is required to meet the consumer demand and preference for healthier, nutritious products. One of the potential approaches is to add some healthy fruits, such as avocado, into cream cheese to make a cream cheese fortified with more nutrients (e.g. monounsaturated fat, vitamins, minerals, etc) without adversely affecting the original sensory properties of cream cheese.

Avocado (*Persea americana* Mill.) is defined as a fruit that is a large berry with a single seed (Schaffer et al., 2013). The avocado flesh consists of 72.3% water, 1.96% protein, 15.4% fat and 8.64% carbohydrate (Dreher & Davenport, 2013). Avocado contains a large proportion of monounsaturated fat with oleic acid (18:1) and a small amount of saturated fat and polyunsaturated fat in its edible portion (USDA, 2019). Monounsaturated fat is one of the healthy fats along with polyunsaturated fat compared to saturated fat (Vessby et al., 2001). The consumption of avocados rich in monounsaturated fat could provide some positive health effects on lipid profiles by increasing the level of good cholesterol in blood, such as high-density lipoprotein (HDL), reducing the bad cholesterol level, such as low-density lipoprotein (LDL) and reducing the lipid serum peroxidation, thus promoting the health of cardiovascular system (Carranza-Madrigal et al., 1997; Wu et al., 2004). Consequently, it provides significant health benefits by preventing hypercholesterolemia and reducing the risk of atherosclerosis (Dwyer et al., 2004; Hozawa et al., 2007; Salonen et al., 2003). In addition, avocado is an important source of some other nutrients, such as vitamins (e.g. vitamin B, vitamin C, vitamin A), minerals (e.g. magnesium, potassium, calcium), fibre and glutathione (antioxidant) (Duester, 2000). In a study conducted by Fulgoni et al. (2010), it was reported that people who consume avocado regularly would have an adequate nutrient intake of dietary fibre, vitamins and minerals.

Avocado cream cheese products are not currently available in the market. The goal of this project was to develop a cream cheese incorporated with avocado that can be acceptable in appearance and quality to consumers. The specific objectives of the study were to determine the effects of various factors on the physicochemical properties (e.g., colour, pH changes, syneresis, texture, flow behaviour and microstructure) of avocado cream cheeses and to conduct consumer sensory evaluation tests. Some factors investigated were different ratios of cream cheese and avocado puree (e.g., incorporation of 0, 10, 20 and 30% w/w avocado puree) and treatments of avocado puree with antioxidants and high-pressure process (HPP) prior to its incorporation into cream cheese.

## **1.2 Overview of Thesis**

This thesis has seven chapters as follows:

Chapter 1 introduces a brief background information about cream cheese and avocados and describes the project's rationale, including the research goal and main objectives.

Chapter 2 is the literature review of this thesis, including the cream cheese-making process, health benefits of avocados, and some vital properties needed to determine a cream cheese product. Also, some previous studies about developing a new type of cream cheese products and some advanced approaches to prevent browning reactions inside avocados are reviewed.

Chapter 3 is the first experimental chapter that describes the use of different concentrations of avocado puree mixed with cream cheese to determine their effects on the quality and stability the avocado cream cheeses over time during storage.

Chapter 4 is the second experimental chapter that describes the use of different processing treatments (antioxidants and high-pressure processing) on cream cheese mixed with 20% avocado puree and their effects on the quality and stability properties of the avocado cream cheeses over time.

Chapter 5 is the last experimental chapter that shows the results of consumer sensory evaluation and acceptability tests of avocado cream cheeses.

Chapter 6 describes the main findings and outcomes of this project. Some suggestions for future study work are also discussed in this chapter.

## Chapter 2. Literature Review

### 2.1 Introduction

Cream cheese is one of the most popular unripened soft cheese products consumed in many developed countries (Jeon et al., 2012). It has a creamy white, slightly acidic taste with a diacetyl flavour and a soft and smooth texture (Fox et al., 2017). It has been widely applied as a spread or salad dressing and used as an ingredient for making desserts, such as cheesecakes (Phadungath, 2005). The standard of identity for cream cheese was first established in 1921 by the Secretary of Agriculture, who administered the Federal Food and Drug Act, which stated that “*Cream cheese is the unripened cheese made by the Neufchatel process from whole milk enriched with cream. It contains in the water-free substance not less than 65% of milk fat.*” (Fox et al., 2017; Lundstedt, 1954).

Cream cheese is versatile and can be used and applied in food products throughout the food industry (Pombo, 2020). It can provide an adequate matrix with flavours, fibres, herbs, and air (Guinee & Hickey, 2009). It can also be supplemented with some fruits and vegetables (e.g. chestnut mushroom and cherry) (Limanowski, 2016; Petrović et al., 2015). Also, some extra ingredients (e.g. probiotics and prebiotics) added in cream cheese products can offer some potential health benefits for consumers, such as boosting an immune system and restoring the balance of microorganisms within the body from added probiotics, thus improving the health of the digestive tract (Limanowski, 2016).

Avocado (*Persea americana*) can be considered a crucial fruit compatible in flavour, taste and texture to cream cheese because of its mild flavour and taste with a soft creamy body and texture when the avocado is combined with cream cheese. Botanically, avocado is a fleshy fruit defined as a single-seeded berry, which differs from many other fruits that contain many seeds inside (Schaffer et al., 2013). Avocado is a good source of some healthy compounds, including fat-soluble vitamins (e.g. vitamins A, D, E and K), which are much more than other fruits, as well as some water-soluble vitamins (e.g. vitamin B6) (Patrícia

et al., 2016) and monounsaturated fatty acids (MUFA). Besides, some lipid compounds in avocados, such as omega-3 fatty acids, phytosterols, tocopherols, and squalene, can also contribute to many health benefits (Santos et al., 2014).

Adding avocado into cream cheese can be challenging and complicated as the avocado pulp is very perishable with a high metabolic rate, giving this fruit a short shelf life (Yahia & Gonzalez Aguilar, 1998). Avocado puree can usually remain fresh only for five days when stored at 4°C, which is very short in its shelf stability compared to other fruits (Pedro et al., 2005; Soliva et al., 2002). Some severe biochemical reactions inside the avocado, such as browning reaction and lipid oxidation, would affect the quality of avocado and deteriorate its colour, flavour and textural properties (Purroy et al., 2011).

There is very limited information available about cream cheese fortified with avocado puree. Although there were quite extensive studies about fortifying cream cheese with fruit-related contents (e.g. cherry concentrate), only a small number of works have been published due to business needs (Limanowski, 2016; Phadungath, 2005). This literature review provides an overall review of cream cheese products, including varieties, manufacture, qualities, defects, sensory evaluation, and some background information about the avocado. This review also discusses the potential benefits of adding avocado puree into cream cheese and some processing treatments applied to the avocado puree to prevent significant deteriorative chemical reactions, such as enzymatic browning to improve the sensory properties of cream cheese with added avocado puree.

## **2.2 Cream Cheese**

### **2.2.1 Chemical Composition and Types of Cream Cheese**

The composition, such as fat content, manufacturing conditions (e.g., degree of heating and shear during curd treatment), and the added hydrocolloids in cream cheese can be varied between different types of cream cheese and different countries. According to the US Food and Drug Administration (FDA), American standard cream cheese must contain more than

33% fat, less than 55% moisture, less than 1.4% salt, and a pH range of 4.3-4.9 (Phadungath, 2005). As for Canadian regulations, cream cheese products should have at least 30% fat content, and in France, some cream cheese products, such as ‘Triple crème’, should have at least 75% fat content (Sanchez et al., 1994).

Cream cheese products are commonly categorised into two main types based on their fat content, including double-cream cheese (DCC) with a fat content from 49% to 60% (w/w) and single-cream cheese (SCC) having fat content between 15% and 30% (w/w) (Guinee & Hickey, 2009). These two types have different textures and consistencies from brittle (hard) to spreadable. DCC is regarded as a type of brittle cream cheese, while SCC is spreadable cream cheese (Fox et al., 2017). These two types of cream cheese are produced by standardising the mixture of milk and cream in the initial stage by adjusting the ratio of fat to protein for manufacturing DCC (2.85:1) and SCC (1.2:1) (Davis, 1976; Phadungath, 2005). Table 2.1 shows the main chemical compositions of SCC and DCC.

**Table 2.1 Typical chemical composition (w/w) of two main types of cream cheese (Kosikowski & Mistry, 1999; Mehanna et al., 2021).**

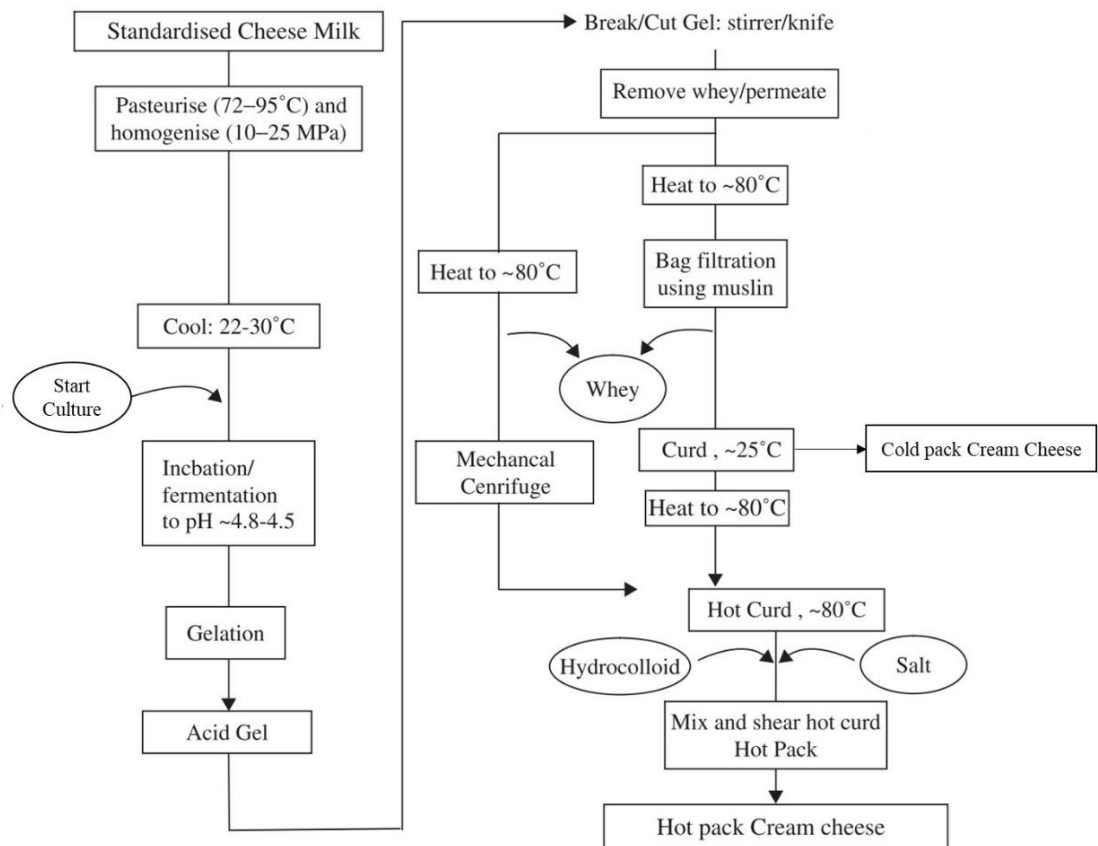
Type	Moisture %	Fat %	Protein %	Carbohydrate %	Ash %	pH
SCC	60.98	35.87	12.10	10.11	2.80	4.74
DCC	57.82	75.99	6.48	1.68	2.45	4.68

SCC is short for single-cream cheese, and DCC is short for double-cream cheese.

### 2.2.2 Cream Cheese Manufacturing Process

A flow diagram for the manufacture of cream cheese is illustrated in Figure 2.1, which indicates two standard methods (hot-pack and cold-pack methods) with a slight difference available for the production of cream cheese products. The main difference is related to the storage life of cream cheeses produced by both methods. Cold-pack cream cheese products usually have a three-week shelf life at below 8°C storage condition while the shelf life of hot pack cream cheese products is usually three months under the same storage condition

as cold pack cream cheese (Barry & Adnan, 2011; Fox et al., 2017; Lucey, 2011).



**Figure 2.1** Flow diagram for the manufacture of cream cheese. Adapted from Guinee and Hickey (2009).

As shown in Figure 2.1, there are various steps involved in the production of cream cheese, including standardisation, pasteurisation, homogenisation, fermentation, drainage of whey, salting, etc., which are described below.

The first step in the production of cream cheese is to standardise the fat content of the initial mixture of raw whole milk and cream to 3-5% fat for single cream cheese or 8-14% for double cream cheese (Phadungath, 2005). After the standardisation, the milk and cream mixture is pasteurised at 72-95 °C for 30-90 sec and homogenised at 10-25 MPa followed by cooling immediately to the suitable setting temperature around 22-30°C before fermentation (Guinee & Hickey, 2009).

In terms of pasteurisation, cream cheese usually has a high proportion of moisture, so it has a greater risk of harbouring pathogens (McSweeney et al., 2017). Pathogenic microorganisms (*Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Salmonella spp*, and *Mycobacterium paratuberculosis*) can contaminate the products directly from animals during storage (Tamime & Robinson, 1999). To make cream cheese free from pathogens, it is necessary to manufacture it from pasteurised milk and pasteurise the cream milk mix during processing (Rinaldoni et al., 2014).

According to Fox et al. (2017), homogenisation is a vital process for several reasons: i) reduce the formation of creaming during the fermentation or acidification stage, thus preventing the compositional heterogeneity of cheese gel, ii) reduce the loss of fat during the whey separation step, iii) help fat globules join in the casein's net formation, and iv) form a smoother and firmer curd by better uniform incorporation of fat into the cheese curd.

After cooling, a starter culture of lactic acid bacteria (*Lactococcus*) is also added, which involves the fermentation of lactose in milk to yield lactic acid. It lowers the pH of the milk, so this step is referred to as acidification or fermentation, eventually leading to coagulation of milk proteins (caseins) (McSweeney et al., 2017). According to Fox et al. (2017), D-type starter cultures are currently used in manufacture, containing *Streptococci* strains that produce the most considerable amount of aroma by metabolising citrate to diacetyl and acetate. These aroma compounds are the main contributors to cream cheese products' flavour characteristics. D-type starter culture quickly decreases the initial pH value, after which the acid-tolerant bacteria, such as *Lactobacilli* strains, is added to continue the fermentation (McGee, 2007).

Sometimes, the addition of rennet is needed as a coagulating agent after locating starter culture to facilitate the gelation of proteins (casein) from the mixture by helping curdling milk to separate the curds and whey so that cream cheese may have a better syneresis behaviour and the desired texture (Ash, 1995; Hinrichs et al., 2004; McSweeney et al.,

2017). However, excessive rennet activity in cheese curd would cause bitterness, which comes from hydrophobic peptides' accumulation formed by the breakdown of caseins due to the excess of rennet (Lucey, 2011; Parente et al., 2017).

As for fermentation, there are two most common incubation (fermentation) conditions: the short-set incubation (around 20 hours) with 5% (w/w) starter culture and the long-set incubation (around 5 hours) using starter culture content of 0.8-1.2% (w/w) (Guinee & Hickey, 2009; Lucey, 2011). The mixture of milk and cream needs to be held at a stable temperature condition until its pH value is reached to an optimum pH range (4.5-4.8) (Fox et al., 2017; McGee, 2007; McSweeney et al., 2017; Phadungath, 2005). Therefore, the pH value is measured to determine the end-time of fermentation to ensure the high quality of the produced cream cheese (Gharibzahedi et al., 2018).

After the fermentation, the resulting cheese curd (acid gel) will be broken by a stirrer or knife and heated to 80°C to separate whey more readily from the curd in a ripening tank for the next drainage step. Separation of whey from the cheese curd is referred to as whey drainage. This step is traditionally conducted by letting the curd drain in a cheesecloth bag (muslin) by gravity for 24 hours (Fox et al., 2017) which takes a long time. The use of a centrifugal separator, as shown in Figure 2.2, is an advanced technique with continuous curd drainage and whey removal (Phadungath, 2005). This cutting-edge device can help the cream cheese be packaged in a relatively aseptic-like and sterile condition because the machine gives cheese curd an enclosed environment from bacterial contamination to offer the cream cheese products a longer shelf life (Collins & Senge, 2004; McSweeney et al., 2017).



**Figure 2.2 Typical centrifugal separator for cream cheese (GEA Group AG, Germany).**

After the whey drainage, the curd is cooled down to 25°C. Then, some salt (0.5-1%) is added to improve the taste. As mentioned above, the cream cheese is then packaged directly as a cold pack with a relatively shorter shelf life. As for the hot-pack cream cheese, the curd is mixed with stabilisers (hydrocolloids), such as guar gum, xanthan gum, locust bean gum, sodium alginate, and carrageenan to reduce the syneresis of cream cheese (Fox et al., 2017). Then it is heated to nearly 80 °C in a mixing tank to get a good mixture. Thus, the texture of hot-pack cream cheese is usually better than the cold-pack one because of this further mixing. Hot curd is pumped to the packaging device and packed even if it is still hot, so the hot pack product has a longer shelf life, around three months under refrigeration (Lucey, 2004).

#### **2.2.4 Versatility of Cream Cheese**

Cream cheese has a soft, smooth texture with mild flavours and taste, making it highly versatile. This means cream cheese is a versatile cheese product mixed with spices, flavours or fruits (Fox et al., 2017). For example, fruit-added cream cheese has been increasingly popular in some countries. Table 2.2 shows some studies involving the addition of fruits into cream cheese. The market for fruit-related cream cheese products in Poland in 2013 was estimated at 348 thousand tons, with a value of 694 million NZD (Limanowski, 2016). One of the reasons for the increasing consumption of cream cheese products is the availability of a wide range of flavours, consistency, texture and additives induced by adding some fruit puree into cream cheese (Gulzar et al., 2015).

**Table 2.2 Some studies involving the addition of fruits into cream cheese.**

<b>Fruits</b>	<b>Type</b>	<b>Content %</b>	<b>Outcomes</b>	<b>References</b>
<b>Cherry</b>	Puree	21.2	Cream cheese's viscosity decreased after mixing.	Limanowski (2016)
<b>Sea buckthorn</b>	Extract	2.2	Sea buckthorn slowed the oxidative process and increased the shelf life of cream cheese.	Ghendov et al. (2020)
<b>Pomegranate</b>	Peel Extract	0.5, 1, 2	Pomegranate peel extracts extended the shelf life of cream cheese by inhibiting bacterial growth.	Shafei et al. (2017)

Besides fruits, adding some other contents have been attempted to develop new products in recent years. In a study reported by Bemmer et al. (2016), an edible oleogel made from rice bran wax and liquid vegetable oils was combined with low-fat cream cheese. This study provided a potential for rice bran wax as a healthy alternative to saturated fat in cream cheese. Petrović et al. (2015) enriched cream cheese with a dry powder of mushroom named *A. aegerita*, and this new kind of cream cheese was found to be more favourable and nutritional than the original cream cheese.

### **2.2.5 Cream Cheese's Quality Requirements and Defects**

#### **Quality Requirements**

Cream cheese products should have a white-based light cream colour with slightly lactic acid and cultured diacetyl flavour and aroma (USDA, 1994). Some off-flavours, including bitterness, sulphide, yeasty and unpleasant flavours, should not be present in the product (Zulkurnain et al., 2008). The texture of the cream cheese should be smooth enough to be spreadable without any lumps or grittiness. Notably, the cream cheese should not have too much indication of cracking or wheying off. The cream cheese products need to be spreadable at room temperature (around 20°C) and should have medium firmness when

they are kept refrigerated (below 7.2°C) (USDA, 1994).

### **Defects**

The most significant defect that can hugely affect cream cheese's quality is syneresis, derived from the structural rearrangements of the casein micelles during the manufacture of cream cheese (Guinee, 2016; Lucey, 2004). The breaking and formation of inter-casein bonds and intra-casein bonds can continue the release of whey or serum during storage. The texture of cream cheese will be grainy, sandy, or chalky, and the flavours of cream cheese will be changed if too much syneresis occurs due to the pH changes caused by syneresis (Lucey, 2011; Macdougall et al., 2019). Stabilisers are added in cream cheese to help solve these defects, such as whey separation (syneresis), by increasing the viscosity of the aqueous phase (Bot, 2006). The most common stabilisers used in cream cheeses are xanthan gum, locust bean gum, and guar gum (Hunt & Maynes, 1997). Although these stabilisers can be used individually, a combination of these three gums was also applied to stabilise cream cheese products. In cream cheese manufacture, stabilisers should be added after the step for whey drainage (whey removal) because adding stabilisers before drainage can interfere with the expulsion of moisture and make it harder to whey out (Collins & Senge, 2004).

### **2.3 Avocado**

Avocado is a fruit that has been increasingly popular around the globe in recent years (DerMarderosian & Beutler, 2002). Botanically, the avocado tree is classified in the plant family of *Lauraceae* and belongs to the genus *Persea* (Schaffer et al., 2013). About 70 species of the avocado genus *Persea* are in America, and 80 species are found in East and Southeast Asia (Colombo & Papetti, 2019). The avocado, *Persea americana*, is the best well-known type of the genus *Persea* (Colombo & Papetti, 2019; Schaffer et al., 2013). Different varieties of avocados, including Bacon, Gwen, Hass and Reed, are widely cultivated in different places worldwide (Alexander, 1978). However, Hass has been one of the most popular varieties worldwide since 1950 because this variety can be planted

under a relatively colder temperature than other varieties (Schaffer et al., 2013). The Hass avocado contains about 136 g edible flesh with a creamy and smooth texture, and the flesh is covered by a thick dark green and bumpy skin (Dreher & Davenport, 2013).

### **2.3.2 Chemical Composition of Avocado**

Avocados are fleshy, single-seeded berries, which differ from most other fruits, and they are a good source of several compounds, including fat-soluble antioxidants (e.g., vitamin E) and monounsaturated fatty acids (MUFA) (Cocci et al., 2006). The sugar content of avocado is usually less than 1 g per serving (30 g), which appears to be the lowest amount compared to other fruits (Comerford et al., 2016). A standard serving of avocados (30 g) has higher nutrients, such as folate, vitamin E, and lutein, compared to other common fruits (i.e., apples, bananas, grapes, and strawberries), which makes avocado become a very efficient vehicle food for delivering essential nutrition in one portion size (Comerford et al., 2016; Dreher & Davenport, 2013; USDA, 2019). The avocado also contains higher unsaturated fatty acids than most fruits and vegetables (Dreher & Davenport, 2013), which could help absorb fat-soluble nutrients (i.e., lutein and carotene) by enhancing nutrient's phytochemical bioavailability. Avocado also has a rich amount of proteins and vitamins (vitamin A, vitamin B and vitamin E) (Patrícia et al., 2016). This fruit also has some medicinal benefits for wounding and stimulating hair growth, and it can effectively deal with diarrhoea and dysentery (DerMarderosian & Beutler, 2002). The nutritional composition of avocados is summarised in Table 2.3 (USDA, 2019).

**Table 2.3 Nutritional composition of the fresh avocado edible portion (USDA, 2011).**

<b>Nutrient/phytochemical</b>	<b>Unit</b>	<b>Value per 100</b>
<b>Water</b>	g	73.23
<b>Energy</b>	kcal	160
<b>protein</b>	g	2
<b>Total lipid (fat)</b>	g	14.66
<b>Carbohydrate, by the difference</b>	g	8.53
<b>Fibre, total dietary</b>	g	6.7
<b>Sugars, total</b>	g	0.66
<b>Minerals</b>		
<b>Calcium, Ca</b>	mg	12
<b>Iron, Fe</b>	mg	0.55
<b>Magnesium, Mg</b>	mg	29
<b>Phosphorus, P</b>	mg	52
<b>Potassium, K</b>	mg	485
<b>Sodium, Na</b>	mg	7
<b>Zinc, Zn</b>	mg	0.64
<b>Vitamins</b>		
<b>Vitamin C, total ascorbic acid</b>	mg	10
<b>Thiamin</b>	mg	0.067
<b>Riboflavin</b>	mg	0.13
<b>Niacin</b>	mg	1.738
<b>Vitamin B-6</b>	mg	0.257
<b>Folate, DFE</b>	µg	81
<b>Vitamin A, RAE</b>	µg	7
<b>Vitamin A, IU</b>	IU	146
<b>Vitamin E (alpha-tocopherol)</b>	mg	2.07
<b>Vitamin K (phylloquinone)</b>	µg	21
<b>Lipids</b>		
<b>Fatty acids, total saturated</b>	g	2.126
<b>Fatty acids, total monounsaturated</b>	g	9.799
<b>Fatty acids, total polyunsaturated</b>	g	1.816

Avocado pulp contains 67-78% w/w moisture, 13.5-24% w/w lipids, 0.8-4.8% w/w carbohydrate, 1.0-3.0% w/w protein, 0.8-1.5% w/w ash, and 1.4-3.0% w/w fibre, and one avocado usually has 140-228 kcal energy density (Soares & Ito, 2000). In terms of micronutrients, avocado contains fat-soluble vitamins (e.g., vitamin A, vitamin E, vitamin K), water-soluble vitamins (e.g., folic acid and ascorbic acid) and minerals (e.g., potassium,

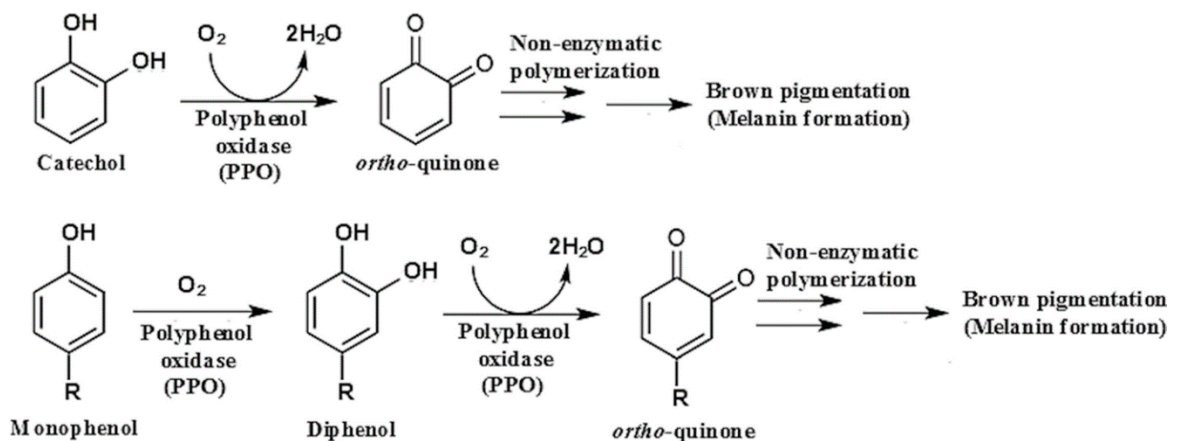
magnesium, sodium, phosphorus, sulphur, silicon) (Dembitsky et al., 2011). Importantly, avocados have a very high potassium level, thus being more than other fruits, which has been linked to protecting the human body from some cardiovascular diseases (Marcos et al., 2019; Patrícia et al., 2016). Avocado can also be an important source of glutathione (around 54  $\mu\text{mol/g}$ ), which is a powerful antioxidant that is associated with human's good physical and mental health and longevity due to its ability to react with free radicals (Lang et al., 2002; Lang et al., 1992; Wang et al., 2012).

### **2.3.3 Shelf Stability of Avocado**

Shelf life is the period where a food product should maintain a predetermined level of quality during storage (Shewfelt, 1986), and avocado's shelf life depends on various conditions, such as storage temperature and climacteric respiration. Avocado fruit, when ripened, has a shelf life of five days at ambient temperature and has about 10-15 days shelf life at 3-4°C refrigeration (Hopkirk et al., 1994; Schaffer et al., 2013), which are considerably shorter than other fruits, and this short period of shelf life after ripen is because of two main factors: avocado's climacteric respiration and the spoilage caused by phytopathogenic fungi (Osuna et al., 2010; Purroy et al., 2011).

Avocado is a climacteric fruit with respiration behaviour following a climacteric pattern. This climacteric respiration has three stages: the preclimacteric minimum (low respiration), the climacteric maximum (maximum respiration), and the postclimacteric stage (Kadam & Salunkhe, 1995). The ripening of avocado causes these respiration stages during the sharp rise in respiration between the preclimacteric minimum and the climacteric peak. When harvested, avocados are mature but unripe, ripening starts after fruits are removed from the tree, and this process will usually take 7-10 days, depending on the cultivar and the storage temperature (Perez et al., 2004). The softening of avocado's peel is generally perceptible in 1-2 days, and the ripeness of avocado's edible portion could be perceptible in 1-3 days with a climacteric rise at room temperature, and the complete ripeness of avocado is finished in 7 days. (Kadam & Salunkhe, 1995).

Avocado is sensitive to enzymatic browning caused by polyphenol oxidase (PPO) (Patricia et al., 2016). PPO is a copper-containing enzyme that catalyses several reactions in the presence of oxygen as shown in Figure 2.3, including the addition of hydroxyl into monophenol to form diphenol (called hydroxylation), the oxidation of diphenol into quinone, and the polymerisation of quinone to form melanin (brown and black pigment). Specifically, PPO, which contains two copper moieties at their active site, catalyses the hydroxylation of the monophenols by oxidising the o-diphenols into o-quinones. After this, another step of nonenzymatic polymerisation of the quinones forms high-molecular-weight pigments (i.e., insoluble and complexed dark-coloured compounds known as melanins). (Peñalver et al., 2005; Queiroz et al., 2008).



**Figure 2.3** The formation of melanin from phenolic compounds (Singh et al., 2018).

### 2.3.3.2 Prevention of Enzymatic Browning

Enzymatic browning control during the processing and storage of avocado is crucial to preserve the avocado's original appearance (Soliva et al., 2002). Browning is also an essential factor in determining avocado's shelf life (Quevedo et al., 2011). Thus, anti-browning becoming one of the main goals for avocado-related processors and researchers. Several chemical agents and physical agents have been researched for inhabiting the enzymatic browning reactions in avocado and some browning-suffered fruits (e.g. apple).

## Chemical Agents

To inhibit enzymatic browning and keep the original colour of fruit's flesh, anti-browning agents, such as antioxidants, reducing agents, acidifying agents, and chelating agents, have been used to control the enzymatic browning of many fruits, including avocado, as PPO activity inhibitors (Almeida & Nogueira, 1995). Table 2.4 shows the details of some treatments based on chemical agents to control the enzymatic browning reactions in avocados and apples.

**Table 2.4 Some anti-browning agents to control the enzymatic browning of fruit.**

Agents	Concentration	Samples	References
Sodium bisulfite	0.1, 0.5 and 1%	Avocado slices and puree	Quevedo et al. (2011)
Ascorbic acid	0.02%	Avocado puree	Soliva et al. (2000) Bustos et al. (2017)
Citric acid	0.002-0.01%	Apple slices	Pizzocaro et al. (1993)
Kojic acid	0.05%	Apple slices	Son et al. (2001)
Ethylenediaminetetraacetic acid	0.25, 0.30 and 0.35%	Avocado puree	Pardo et al. (1991)
Hexylresorcinol	0.1, 0.2 and 0.3%	Apple slices	Ribeiro et al. (2020)

## Physical Agents

**Heat treatment.** Temperature is a significant factor affecting many biochemical reactions and enzymes' activity (Singh et al., 2018). The sensitivity of PPOs to heat treatment is different depending on several conditions (e.g., fruits, cultivars, origins, and maturity). However, usually, when the temperature was around 70–95°C, the activity of PPOs would be destroyed in many fruits (e.g., apple, avocado, pineapple, and mango) (Başlar & Ertugay, 2013; Chutintrasri & Noomhorm, 2006; Ndiaye et al., 2009; Weemaes et al., 1998). However, Pedro et al. (2005) found that heat treatment would be somewhat detrimental to avocado quality as a high temperature may cause undesirable reactions that could accelerate

the deterioration of avocado puree to turn into browning, nutritional losses and off-flavours.

***High-pressure processing (HPP).*** High-pressure processing of food materials provides an effective alternative to conventional thermal treatment to process avocados. HPP has been widely researched to impart longer shelf life of avocado slice, paste, and pulp by inhibiting the browning reactions (Jacobo-Velázquez & Hernández-Brenes, 2010; Palou, Hernández-Salgado, et al., 2000; Weemaes et al., 1999; Woolf et al., 2013). It is a novel processing technique used for avocado slices and avocado pulp, reducing browning and retaining the avocado pulp fresh (Dunne, 2008). PPOs can be deactivated when exposing to high pressure in the range of 300–800 MPa without negatively affecting nutrients and flavour compared to conventional heat treatments (Palou, Lopez-Malo, et al., 2000; Rico et al., 2007). Similarly, Woolf et al. (2013) found that HPP treatments from 400 MPa to 600 MPa could successfully slow down the respiration rate of avocado slices, and more than 400 Mpa pressure would cause a relatively lower PPO activity in avocado slices.

***Pulsed light.*** Pulsed light is another new technique using a wide range of high-peak pulses in short time intervals on foods to inactivate microorganisms and enzymes (Woodling & Moraru, 2007). It is an alternative non-thermal technology to extend the shelf life of fresh-cut fruit products without compromising their nutritional value, such as apple, avocado, and mango (Charles et al., 2013; Gómez et al., 2012; Ramos-Villaruel et al., 2014). It has been researched that when avocado pulps were exposed to 14 J/cm<sup>2</sup> treatment of pulsed light, avocado retained the highest hue colour values with minor browning (Aguilo-Aguayo et al., 2014).

#### **2.3.4 Health Benefits of Avocado**

Some studies have shown that the consumption of diets enriched with avocado has beneficial health effects on cardiovascular disease, hypercholesterolemia and type-II diabetes by controlling the blood lipids such as lowering LDL-cholesterol and triglyceride content, increasing HDL-cholesterol and increasing insulin sensitivity (Carranza et al.,

1997; Dreher & Davenport, 2013; Grant, 1960; Lerman et al., 1994). Table 2.5 shows some clinical trials conducted to investigate the health benefits of avocado on the cardiovascular system.

**Table 2.5 Some clinical studies on the health effects of avocado on the cardiovascular system.**

<b>Methods</b>	<b>Conclusions</b>	<b>References</b>
<ul style="list-style-type: none"> <li>- By opening label study for 4 weeks.</li> <li>- Patients from 27-72 years old.</li> <li>- Offering patients 0.5–1.5 California avocados per day additionally.</li> </ul>	The daily addition of California avocados would benefit body weight control and total cholesterol (TC).	Grant (1960)
<ul style="list-style-type: none"> <li>- A randomised, crossover study for 3 weeks.</li> <li>- Patients from 37–58 years old</li> <li>- Two diets were offered:               <ol style="list-style-type: none"> <li>(1) High, primarily the avocado diet.</li> <li>(2) High complex carbohydrates low-fat diet.</li> </ol> </li> </ul>	Avocado enriched diet could be more effective in promoting heart-healthy lipid profiles for women.	Colquhoun et al. (1992)
<ul style="list-style-type: none"> <li>- A randomised and crossover study for 4 weeks.</li> <li>- Women patients offered with type 2 diabetes from 56 ± 8 years old.</li> </ul>	Some avocados were partially replaced with other dietary fats in patients who had type-II diabetes favourably affected serum lipid profile and maintained adequate glycaemic control.	Lerman Garber et al. (1994)
<ul style="list-style-type: none"> <li>- A randomised, controlled, and parallel study.</li> <li>- Male and female adults from 40.8 ± 8.9 years old.</li> <li>- Avocado (200 g) would substitute 30 g of mixed fat for a control diet without avocado.</li> </ul>	The consumption of avocados within an energy-restricted diet would not compromise weight loss, lipoproteins, or vascular function.	Pieterse et al. (2005)

Some clinical studies also showed that xanthophyll present in avocados has antioxidant activity and DNA protective effect of promoting healthy ageing (Dreher & Davenport, 2013). Also, a significant inverse association was shown between the intake of vitamin C, β-cryptoxanthin, beta-carotene, lutein and zeaxanthin from the avocado pulp and the frequency of a biomarker of cumulative DNA damage, which is called chromosome translocation (Yong et al., 2009).

The consumption and application of avocado-related products (i.e., avocado puree extracts, avocado seed extracts) have been widely used for skin health (Nayak et al., 2008; Rerksuppaphol & Rerksuppaphol, 2006; Rosenblat et al., 2011). Facial skin can be damaged due to oxidative stress and inflammation when frequently exposed directly to sunlight and other invisible radiations (Ashton, 2005). A high proportion of some carotenoids (e.g. lutein, zeaxanthin) in avocado can help protect the human skin from damage caused by visible light and UV radiation and enhance wound healing activity (Roberts et al., 2009).

According to various *in-vitro* studies using human cancer cell lines, avocado also has anti-cancer potentiality (Ding et al., 2009; Jones et al., 1992). This is because avocado contains many different bioactive phytochemicals, such as carotenoids, terpenoids, D-mannoheptulose, phenols, glutathione, and person A and B anti-carcinogenic properties (Dreher & Davenport, 2013). Also, a previous controlled study based on a large population showed that a higher intake of avocado pulp would significantly decrease the risk of pharyngeal and oral cancer (Castillo Juárez et al., 2009).

#### **2.4 Textural and Rheological Properties of Cream Cheese**

Cream cheeses' textural and rheological properties are significant for their popularity and applications as a food ingredient in dips, flavoured spreads, and desserts (Brighenti et al., 2008; Muir & Hunter, 1992). The texture is one of the significant sensory properties that can be perceived by the senses of hearing (oral texture), sight (visual texture) and touch (tactile texture) during consumption (Brennan, 1988; Delahunty & Drake, 2004). Technically, the texture of typical commercial cream cheese products is smooth and uniform, without graininess or lumps at room and cold temperatures (Tamime & Robinson, 1999).

However, many factors can affect the textural properties of cream cheese products. The

final texture of cream cheese could vary due to its compositions (e.g. fat content) and manufacturing conditions (e.g. degree of heating and homogenisation during curd treatment) (Guinee & Hickey, 2009). According to Brighenti et al. (2008), full-fat cream cheeses had significantly greater hardness than the Neufchatel and fat-free cream cheeses, and higher homogenisation could reduce the particle size and narrow the distribution of particle size resulting in firmer cream cheese (Ningtyas et al., 2018). Also, traditional thermal pasteurisation treatments of cream cheese curd during manufacture could change the structure and physical-chemical properties of fat globules and proteins so that the final cream cheese texture can be dramatically affected, such as its firmness and elasticity (Ningtyas et al., 2018).

The rheological properties of cream cheese are determined by measuring the cheese's responses to the strains or stresses, such as shearing and compression (McSweeney et al., 2017). These responses are encountered and applied during the processing of cheeses, including shredding, slicing, portioning and grating, and the consumption of cheeses (e.g. spreading, slicing, masticating and chewing). Rheological properties are essential as they can affect cream cheese's elasticity, viscosity, and viscoelasticity related to cheese products' structure, composition, and strength (Fox et al., 2017). In addition, rheology properties affect cream cheese's ability to retain a shape when it is stacked and the ability to retain the gas inside (McSweeney et al., 2017). Also, the rheological properties of cream cheese, which will also influence texture and mouthfeel, affect cream cheese's flavour and aroma properties (Ash, 1995).

The rheological properties of cream cheese can be influenced by many factors, such as the mixing method of cheese curd, the degree of heat, the value of pH, and the time of heating (Ningtyas et al., 2018). However, if cream cheese products are used as an ingredient, the rheological properties will be determined by other food products that are mixed with cream cheese (Fox et al., 2017).

### 2.4.5 Sensory Evaluation of Cream Cheese

The sensory test of food products can be regarded as the most powerful method to describe a food product's characteristics in terms of attributes and intensities (Pujchakarn et al., 2016). This method has been widely used to characterise food products' characteristics and qualities, including cream cheese. For example, some cream cheese attributes are difficult to test directly, such as spreadability, which is one of the most critical textural properties for cream cheese (Breidinger & Steffe, 2001). To determine spreadability, a sensory test by acquiring the score from the 9-point-unstructured scale is usually to be conducted (Wendin et al., 2000). The essential attributes and definitions commonly analysed by sensory evaluation of cream cheese are summarised in Table 2.6.

**Table 2.6 Essential attributes and definitions associated with the sensory evaluation of cream cheeses.**

<b>Appearance</b>	
<b>Attributes</b>	<b>Definition</b>
<b>Yellow colour</b>	White = 1, Yellow = 9
<b>Granularity</b>	Smooth cheese = 1, Grainy cheese = 9
<b>Watery</b>	A wet and shiny look
<b>Compact</b>	Porous = 1, Compact = 9
<b>Texture and mouthfeel</b>	
<b>Attributes</b>	<b>Definition</b>
<b>Firmness</b>	Slightly firm = 1, Very firm = 9
<b>Smoothness</b>	Slightly smooth = 1, Very smooth = 9
<b>Granularity</b>	Smooth cheese = 1, Grainy cheese = 9
<b>Flavour and Taste</b>	
<b>Attributes</b>	<b>Definition</b>
<b>Acidity (sourness)</b>	Fresh sourness, like yoghurt Slightly sour = 1, Extremely sour = 9
<b>Saltiness</b>	Slightly salty = 1, Extremely salty = 9
<b>Creaminess (butter-like flavour)</b>	Slightly creamy = 1, Extremely creamy = 9

**Adapted from:** Kalab and Modler (1985), Modler et al. (1985), Wendin et al. (2000), and Napolitano et al. (2010).

### 2.5 Conclusions

The purpose of this review is to understand the basic knowledge of cream cheese and

avocados about their chemical composition, manufacture, characterisations, health benefits, and potential. Cream cheese can be a fundamental matrix for delivering the avocado puree because of its compatible chemical and physical characteristics, such as textural properties, rheological properties and high fat composition. Therefore, to improve cream cheese products, avocado-fortified cream cheese can be further developed by finding how to stabilise avocado pulps from degradation in cream cheese during storage, such as slowing enzymatic browning. The avocado-fortified cream cheese can be formulated by simply mixing the cream cheese with avocado puree. This novel product development has many potential applications as a cream cheese product with health benefits offered by avocado puree containing various bioactive compounds. However, the intricate part of developing the cream cheese containing avocado puree can be: i) how to effectively inhibit the degradation of avocado puree (e.g., colour change due to enzymatic browning and lipid oxidation) and ii) understand the consumer acceptability of this new product. Based on the knowledge from this literature review, it is believed that HPP treatment and antioxidants can be used to extend avocado's shelf life, including its prevention from enzymatic browning. Although some researchers have conducted studies on the development of cream cheese mixed with other fruits (e.g., cheery, sea buckthorn, and pomegranate), there is no report yet on avocado-enriched cream cheese. Therefore, the objective of this project was to develop a cream cheese product combined with the avocado puree with desirable sensory properties.

## **Chapter 3. Effects of Concentration of Avocado Puree on the Properties and Stability of Avocado-fortified Cream Cheeses during Storage**

### **3.1 Abstract**

The growing demand of consumers for healthy food products led to an increased necessity for developing new products with improved functional properties. This study aimed to develop a novel cream cheese product enriched with fresh avocado puree and investigate the effect of various avocado puree concentrations (0, 10, 20, and 30% avocado puree) on changes in some quality and stability parameters of cream cheeses during storage. Chemical analysis revealed that avocado-enriched cream cheeses had more moisture, fat, and ash contents than the control sample (cream cheese without adding avocado puree) and showed a softer texture with less spreadability. The cream cheese sample also had a higher syneresis and lower viscosity when combined with avocado puree. The microstructure of cream cheeses analysed by confocal laser scanning microscope (CLSM) was not significantly influenced by the addition of avocado puree, except for the presence of more serum phase area in the cream cheese structure. Texture profile analysis (TPA) indicated that all avocado-enriched cream cheeses had similar adhesiveness values to each other. However, the addition of more avocado puree caused more significant colour changes and instability during storage. Also, avocado puree induced the growth of undesirable microorganisms, such as yeasts and moulds, after 3 weeks of storage of the cream cheeses fortified with relatively higher concentrations of 20 and 30% avocado puree, which needs to be solved in the future study. However, it was not detected in the control cream cheese sample without containing avocado puree and the cream cheese samples containing 10% avocado puree during the whole storage period of 4 weeks. Nevertheless, avocado-fortified cream cheese samples showed stability in their textural properties during the 4-week storage, and the sensory test showed that participants preferred a cream cheese sample added with 20% (w/w) avocado puree. Overall, the results indicate that the cream cheese products added with avocado puree had some instability due to changes in colour and flow behaviours during storage. This could be related to the chemical composition of cream cheese resulting

in a decrease in protein and carbohydrate contents while an increase in moisture and fat contents by the addition of avocado puree and a combined effect of some undesired chemical reactions resulting from chlorophyll degradation and enzymatic browning. Therefore, further work is needed to solve some undesired changes in the sensory and chemical properties when the avocado is incorporated into cream cheese.

### **3.2 Introduction**

Cream cheese is one of the most predominant and popular cheese products in the dairy industry (Apilado et al., 2013). The consumption of cream cheese has had a constant increase since the 1980s, which indicated potentially generating massive profits (Yoshida & Kubota, 1985). Although cream cheese products are increasingly popular, health-conscious consumers may not be willing to buy the original cream cheese product due to its high-fat content (Apilado et al., 2013). Thus, some studies have been conducted to widen a variety of cream cheese products to cater to health-conscious consumers through adjusting its nutritional value by adding and mixing with other nutritious fruits (e.g., cherry concentrate) (Bahrami et al., 2015; Bemer et al., 2016; Limanowski, 2016).

Avocado (*Persea americana*) may be considered an ideal fruit to be mixed with cream cheese due to its higher nutritional value. This fruit is rich in protein content and contains fat-soluble vitamins, usually lacking in other fruits, such as vitamins A, D and E (Ashton, 2005). Avocados can also be regarded as a good source of several essential lipid compounds, such as monounsaturated fatty acids (MUFA) (Ding et al., 2007). In addition, this fruit has been well-known worldwide for its lipid compounds (e.g., omega-3 fatty acids, tocopherols, squalene, and phytosterols) (Santos et al., 2014). Therefore, the addition of avocado puree into the cream cheese may increase its nutritive value, including improving cream cheese's lipid compounds.

However, fresh-cut avocados without any chemical or physical treatments can promote microbial degradation, biochemical changes, and physiological deterioration (Bustos et al.,

2015). Thus, the avocado pulp is highly perishable due to its high metabolic rate and enzymatic browning (Yahia & Gonzalez Aguilar, 1998). Specifically, enzymatic browning is a severe problem in avocados, and this reaction can produce colour alterations to reduce avocado's commercial value by adversely affecting the avocado's colour to make it unacceptable to consumers (Pedro et al., 2005). Therefore, it is important to understand how addition of avocado pulp can influence the quality and sensory properties of cream cheese products due to some physicochemical changes and deterioration of avocado pulp.

Nevertheless, very little information is available about the effect of incorporating avocado at different concentrations on the physicochemical and microbial stability of cream cheese, including cream cheese's textural and rheological properties and colour stability. Therefore, this study was conducted to find the effects of avocado puree's concentrations on the stability and quality of cream cheeses during storage at 4°C for 4 weeks and determine an optimal level of inclusion of avocado puree into cream cheese. By comparing cream cheeses with different avocado puree levels, avocado puree's effects on cream cheese's textural and rheological properties would also be identified. The specific objectives of this study were to determine the changes in colour, microbial, textural, rheological, and sensory properties of avocado-fortified cream cheese. This study may fill some existing gaps in baselines about how to develop a safe and acceptable cream cheese product fortified with avocado puree.

### **3.3 Materials and Methods**

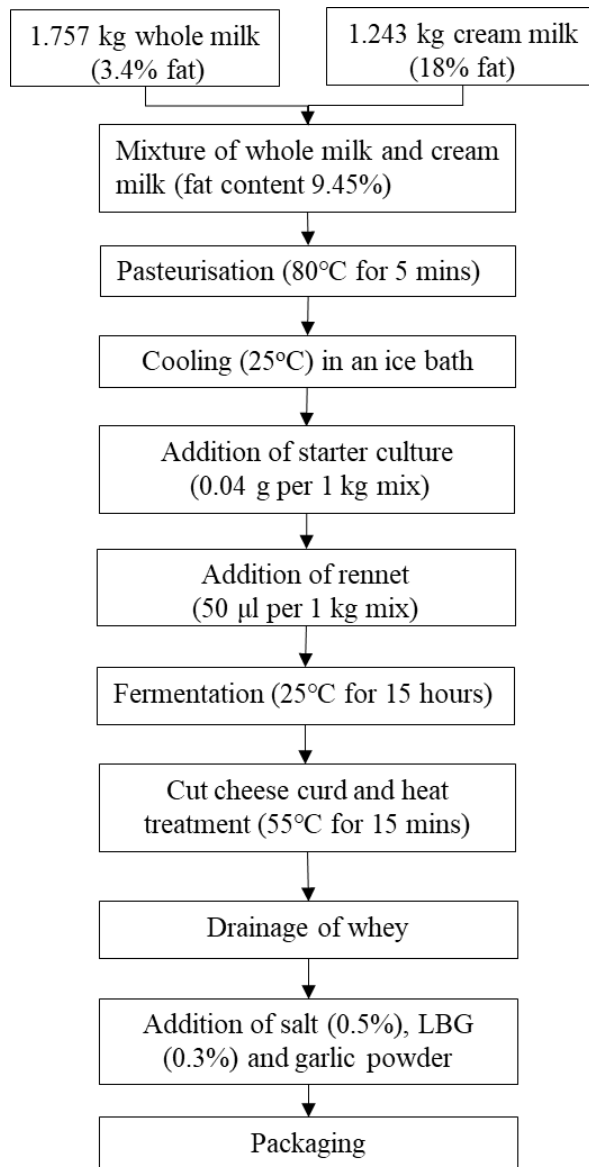
#### **3.3.1 Materials**

The milk and dairy ingredients used in producing cream cheese were as follows: whole milk (Anchor Milk Blue Top) (Fonterra Brands NZ Ltd, New Zealand) containing 3.3% protein, 3.4% fat and 4.8% carbohydrate, Fresh Organic Half & Half milk (Puhoi Valley, New Zealand) containing 2.8% protein, 18% fat, and 3.8% carbohydrate which is creamier milk produced by blending milk and cream. The nutritional information (composition) of the whole milk and Half & Half milk can be found in Appendices 1 and 2. The other

ingredients used include sea salt (Country Trading Co., New Zealand), garlic powder (Woolworths, New Zealand), Fresh Cheese Culture containing *Lactococcus lactis* subsp. *cremoris*, *Lactococcus lactis* subsp. *lactis*, *Lactococcus lactis* subsp. *lactis* biovar *diacetylactis* and *Leuconostoc* (Mad Millie, New Zealand), Vegetarian Liquid Rennet (Mad Millie, New Zealand), and locust bean gum (LBG) (Hawkins Watts, New Zealand). Fresh avocados (Hass avocados) were purchased from a local supermarket (PAK'nSAVE, New Zealand).

### **3.3.2 Preparation of cream cheese**

A flow diagram of producing a batch of 1 kg cream cheese based on the methods adapted from Ningtyas et al. (2018) and Phadungath (2005) is illustrated in Figure 3.1. Briefly, the whole milk was mixed thoroughly with the Half & Half milk (referred to as “cream milk” hereafter) in a glass jar with a cap by a high shear mixer (L5M-A, Silverson, UK). The milk-cream mixture was heat-treated at 80°C for 5 minutes for pasteurisation in a temperature-controlled water bath (T100, Grant Instruments, UK). After the pasteurisation, it was cooled to 25°C immediately by placing in an ice bath. Then, the starter culture was added into the milk-cream mix, followed by adding the rennet. After stirring gently, the mix was fermented at 25°C for 15 hours in the water bath until its pH value reached around 4.6. The curd was cut into pieces with a knife and then put in a closely tied linen cloth and suspended in a stainless-steel drum for 6 hours to expel whey out from the curd without any pressing. After the whey drainage, other ingredients (0.5% w/w salt, 0.1% w/w garlic powder, and 0.5% w/w LBG) were added into the cheese curd and mixed by a hand mixer (Living & Co 250W Stick Mixer, New Zealand).



**Figure 3.1** Flow diagram of producing a batch of 1 kg of cream cheese adapted from Ningtyas et al. (2018) and Phadungath (2005).

### 3.3.3 Preparation of Avocado Puree and Avocado Cream Cheeses

Fresh avocados purchased from a local supermarket were stored at ambient temperature till fully ripen in 4 days and then cut into halves lengthwise around the seed using a knife. After removing the seed, the avocado flesh (pulp) was gently scooped out of the avocado halves using a spoon. The halved avocado flesh was then vacuum-packaged using a vacuum packaging machine (Type-C300, MULTIVAC, Germany) and stored at -20°C until utilised (Figure 3.2). Avocado puree was prepared from the frozen avocado fresh by blending it in

a clean small glass bowl using a hand mixer (Living & Co 250W Stick Mixer, New Zealand) after thawing the frozen avocado at 4°C overnight. Then, avocado cream cheeses were made by adding the avocado puree into the cream cheese at different ratios (0, 10, 20, and 30%) and mixing them uniformly by the hand mixer. The avocado cream cheese samples prepared were vacuum packaged in the vacuum bags and stored at 4°C for 4 weeks (0, 7, 14, 21 and 28 days). The sample codes of cream cheese samples after mixing with avocado puree are shown in Table 3.1.



**Figure 3.2** The vacuum packaged avocado halves.

**Table 3.1** The sample codes of avocado cream cheese samples prepared by mixing avocado puree with cream cheese at different ratios (w/w).

Sample Code	Avocado	Cream Cheese
<b>0%AVP</b>	0%	100%
<b>10%AVP</b>	10%	90%
<b>20%AVP</b>	20%	80%
<b>30%AVP</b>	30%	70%

### 3.3.4 Analysis of Samples

#### pH measurement

The pH values of avocado cream cheeses were measured at 20°C by using a pH meter (PB-11, Sartorius, Germany). The pH meter was calibrated with two standard pH buffers solutions (pH 4.0 and 7.0) prior to its use. Each sample was analysed in triplicate during

storage at 4°C for 4 weeks (0, 7, 14, 21 and 28 days).

### **Chemical composition of avocado cream cheeses**

The avocado cream cheese samples were analysed for their chemical composition, such as moisture, proteins, fat, and ash, using standard AOAC procedures (AOAC, 1995). In this study, the carbohydrate and dietary fibre contents were not analysed, but the content of carbohydrate combined with fibre was estimated via calculation. Moisture content was analysed using an air oven method by placing the samples in an oven maintained at 105°C overnight. The determination of ash content was carried out by using the dry ashing method. The cream cheese samples were dried first in an air oven at 110°C overnight and then ashed at 550°C in a muffle furnace (A-550, Vulcan, USA) for 8 hours. The crude protein content was measured based on the measurement of nitrogen content by using the Kjeldahl method. A value of 6.38 was applied as a conversion factor to convert nitrogen content to protein content. The crude fat content of cream cheese samples was determined using the Mojonnier method with diethyl ether and petroleum ether as fat extraction solvents.

### **Colour measurement**

The colours of cream cheese samples were also analysed using a colour meter (Minolta Chroma Meter CR-300, Minolta Co. Ltd, Japan), and their colours were expressed numerically in CIE L\*, a\* and b\* values. The colourimeter used was calibrated before its use against a CR-300 white calibration plate. The samples were placed into a petri dish (30 mm in diameter) for the colour measurement, which was carried out by placing the petri dish containing samples on top of the measuring head of the CR-300. Each sample was tested in triplicate during storage (0, 7, 14, 21 and 28 days). In terms of the CIE L\*a\* b\* scale, the L\* value represents lightness which ranges from 0 (black) to 100 (white), the a\* value represents the redness (+a) and greenness (-a), and the b\* value represents the yellowness (+b) and blueness (-b). Based on the results of L\*, a\*, and b\* values, total colour difference denoted as  $\Delta E^*$  was calculated between two colours using the  $\Delta E^*$  equation below by subtracting sample minus standard values where a sample at day 0 was considered

as a standard sample in the calculation. The greater the  $\Delta E^*$  value, the more significant the total colour difference between colours of the two samples.

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}$$

### **Viscosity measurement**

The viscosity of cream cheese samples was measured, based on the method reported by Brighenti et al. (2018) and Ningtyas et al. (2018), by using a rheometer (AR550, TA Instruments Ltd., USA) equipped with a cone and plate geometry. The data of this test collected was analysed by the TA's Rheology Advantage data analysis software (version 5.7.0, TA Instrument Ltd., USA). To measure the flow properties, the rheometer was set to perform the shear rate sweep test of the target sample, and the shear rate was set from 0-500 s<sup>-1</sup> using a 40 mm diameter cone with a 2° angle. All measurements were carried out at 20°C. For each test, a 2 g sample was loaded onto the Peltier plate by a syringe directly from the refrigerator (4°C) and left the sample in the test room until the sample had the sample temperature as the ambient temperature (20°C) to ensure the rheological properties of the sample do not change due to the temperature change. Each sample was analysed at least in duplicate during the storage (0, 7, 14, 21 and 28 days).

### **Texture analysis of cream cheeses**

A texture analyser (TA-XT plus, Stable Micro Systems Ltd., UK) was used to analyse the textural properties of cream cheese samples with a 5 kg load cell based on the method from Ningtyas et al. (2018). A 50 g sample was loaded in an acrylic cylindrical container (90 ml, 53 mm diameter Specimen Container, Thermo Fisher Scientific, USA), and the container was then tapped gently to remove air bubbles. A cone-shaped acrylic probe (TA15/1000, 45° angle, 30 mm diameter) was used to compress the samples with the following settings: test speed 1 mm/s, return speed 2 mm/s, distance 15 mm and trigger force 4.0 g at a data acquisition rate of 100 points. Two successive compressions were carried out on each sample directly in the same container. The Exponent Software (Version 6,1,15,0, Stable Micro Systems Ltd., UK) was used to generate the force-time curve and the values of

texture attributes, such as firmness, spreadability and adhesiveness, were measured and recorded. The texture measurement for each sample was conducted in triplicate during storage (0, 7, 14, 21 and 28 days).

### **Syneresis of cream cheeses**

The syneresis of cream cheese samples was determined following the method adapted from Wolfschoon-Pombo et al. (2018). Briefly, after the preparation of cream cheeses, the syneresis of samples was measured after two days of storage at 4°C. The samples (50 g) were loaded into conical centrifuge tubes (50 ml size) (Thermo Fisher Scientific, USA) and centrifuged for 20 minutes at 5000 x g at 4°C twice. Then, the serum phase was decanted and its weight was determined. The syneresis (%) was calculated according to the equation shown below:

$$\% \text{ syneresis} = \frac{\text{serum separated (g)}}{\text{sample (g)}} \times 100$$

### **Microstructure of cream cheeses**

Avocado-fortified cream cheese samples were analysed by a confocal laser scanning microscopy (CLSM). Samples were placed in a cavity slide and added with 50 µL of 0.2 g/L Nile Red (for oil droplet staining) and Fast Green (for protein staining) before a coverslip covered the sample. Imaging was captured by the Leica DM6000B SP5 confocal laser scanning microscope system with LAS AF software (version 2.7.3.9723, Leica Microsystems CMS GmbH, Germany). Images were acquired with an HCX PL APO CS 40x oil (N.A.1.25) using the super-resolution mode. Nile Red and Fast Green were sequentially imaged from excitation at 488 nm (argon laser) and 633 nm (HeNe 633 laser), respectively. Emission collection was conducted at 498-569 nm and 643-787 nm, respectively

### **3.3.5 Microbiological analysis of avocado cream cheeses**

#### **Total coliform count**

The total coliform count in cream cheese samples was measured by using the 3M™ Petrifilm™ Coliform Count Plates (3M Company, USA). The samples (1 g) were placed in stomacher bags (177 x 305 mm, VWR-Global Science) and mixed with 9 ml of 0.1% peptone water, and then shaken by using a stomacher paddle blender (IUL Instruments, Spain) for 2 minutes. One ml of the diluted samples was placed onto the centre of the bottom film. After the roll-top film back down, a petrifilm plastic spreader was placed on the top film over the inoculum and pressed down gently. Then the plates were incubated with the clear side up in stacks of up to 20 in an incubator (Acorn Scientific, New Zealand) at 37°C for 24 hours. All samples were analysed in triplicate at different time intervals during storage (0, 7, 14 and 28 days).

#### **Yeast and mould count**

The yeast and mould count in avocado cream cheese samples was measured using 3M™ Petrifilm™ Yeast and Mould Plates (3M Company, USA) following the procedures described above. After the inoculation, the plates were cultured at 25°C for 72 hours for the first check. Then the plates were put back in the incubator for another 48 hours with the clear side up in stacks of no more than 50. All the samples were analysed in triplicate.

### **3.3.6 Sensory evaluation of avocado cream cheeses**

Consumer acceptability is highly important in developing a new product development. For this reason, both qualitative and quantitative sensory evaluations were conducted to gain insights into consumers' preferences regarding the cream cheeses fortified with different levels of avocado puree. The sensory evaluation was conducted in a local net cafeteria (Albany, Auckland, New Zealand), where 37 participants were recruited to taste and evaluate the avocado cream cheese samples. Participants were asked to evaluate and rate what sample they like most and least as well as their overall liking and likings of specific attributes, including flavour, colour, aftertaste, sourness, creaminess, smoothness, firmness,

etc. This sensory evaluation was conducted using an iPad installed with RedJade (RedJade Sensory Software, USA). The RedJade software collected all the results. The Massey University Human Ethics Committee reviewed and approved this sensory evaluation: Southern A, Application 4000023103. The list of sensory questionnaires can be found in Appendices 3 and 4.

### **3.3.7 Data Analysis**

All the measurements of samples described in the above (pH, colour, viscosity, texture, syneresis, and microbial count) were carried out at least twice for each sample from at least duplicate experiments. The results obtained were analysed by a Minitab Statistical Software (Minitab 19 Statistical Software, USA). The one-way analysis of variance (ANOVA) was applied to examine the differences between the mean values at a significance level ( $p < 0.05$ ).

## **3.4 Results and Discussions**

### **3.4.1 Chemical Composition of Avocado Cream Cheeses**

Avocado cream cheese samples containing different levels of avocado puree (0, 10, 20 and 30% AVP) were analysed to determine moisture, protein, fat and ash content, as shown in Table 3.2. The percentages of moisture, protein, fat, ash and carbohydrate content of cream cheese sample without containing avocado puree (0% AVP), referred to as the plain cream cheese, were 68.52, 12.89, 9.57, 0.15 and 8.99%, respectively. The results were similar to those of cream cheese samples reported by Monteiro et al. (2009), which had 51.43% moisture, 7.85% protein, 36.40% fat, and 1.59% ash.

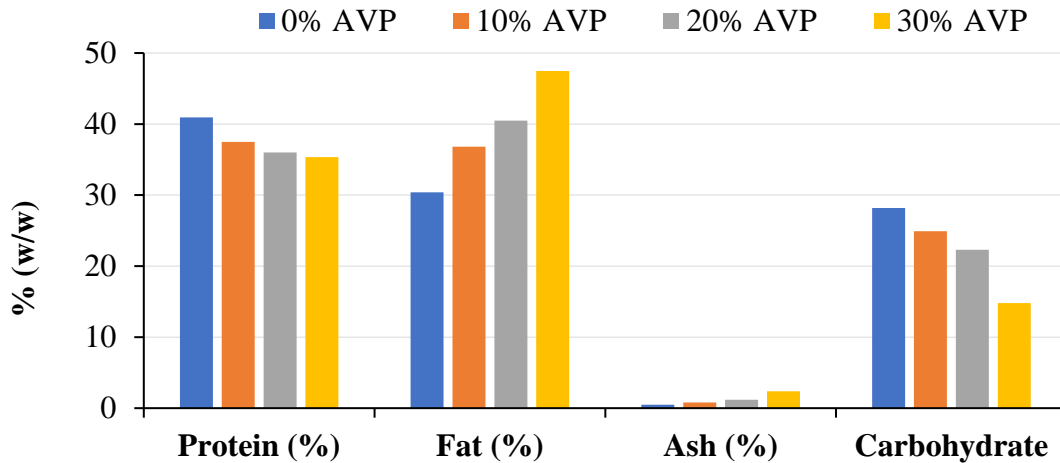
In this study, when the avocado puree was incorporated into the plain cream cheese at different levels, the moisture content in all avocado-fortified cream cheese samples (10%AVP, 20%AVP and 30%AVP) was higher than that of the plain cream cheese sample (0%AVP). The results showed a gradual increase in the moisture content from 68.52% to 70.85, 72.12 and 74.85%, respectively, with increasing avocado content. Also, a similar

trend was observed for the fat and ash contents, which increased from 9.57% to 11.94% fat and from 0.03% to 0.60% ash when comparing the plain cream cheese with the 30% avocado fortified cream cheese sample (30%AVP). This means the avocado puree had a relatively higher content of moisture, fat and ash than the plain cream cheese, thus contributing to a relative increase in the content of those components. On the other hand, for the protein content, the addition of avocado puree decreased the level of protein content in the cream cheese. The protein content for cream cheese samples (0%AVP, 10%AVP, 20%AVP, and 30%AVP) was 12.89%, 10.93%, 10.04%, and 8.89%, respectively. Also, the content of carbohydrates which was 8.99% in the plain cream cheese was observed to significantly decrease from 7.26% to 3.72% with a gradual increase in the level of avocado puree incorporated from 10% to 30% as shown in Table 3.2. The pronounced decrease in the carbohydrate content of cream cheese samples observed with increasing avocado content was mainly attributable to the significant relative increase in the fat content as shown in Figure 3.3, which shows the chemical composition expressed as percentages on the dry matter basis.

**Table 3.2 The chemical composition (% w/w) of avocado cream cheese samples analysed (n=6).**

<b>Components</b>	<b>0% AVP</b>	<b>10% AVP</b>	<b>20% AVP</b>	<b>30% AVP</b>
<b>Moisture (%)</b>	68.52 ± 0.52	70.85 ± 0.74	72.12 ± 0.02	74.85 ± 0.90
<b>Protein (%)</b>	12.89 ± 0.37	10.93 ± 0.79	10.04 ± 0.12	8.89 ± 0.08
<b>Fat (%)</b>	9.57 ± 0.45	10.73 ± 0.58	11.29 ± 0.63	11.94 ± 0.39
<b>Ash (%)</b>	0.15 ± 0.01	0.23 ± 0.02	0.33 ± 0.01	0.60 ± 0.07
<b>Carbohydrate (%)<sup>a</sup></b>	8.99 ± 1.33	7.26 ± 2.11	6.22 ± 0.78	3.72 ± 1.37
<b>Total solids (%)</b>	31.48 ± 0.52	29.15 ± 0.74	27.88 ± 0.02	25.15 ± 0.9

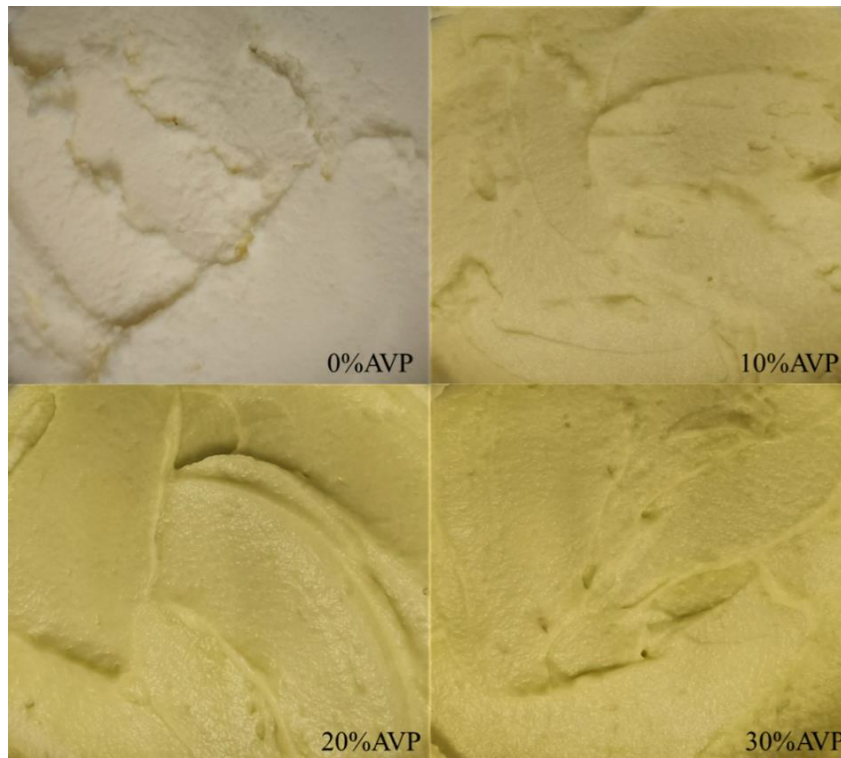
<sup>a</sup>Estimated via calculation. The term ‘carbohydrate’ for the cream cheese samples containing avocado puree (10, 20, and 30% AVP) means carbohydrate plus dietary fibre.



**Figure 3.3** The protein, fat, ash, and carbohydrate content in avocado cream cheese samples on a dry matter basis.

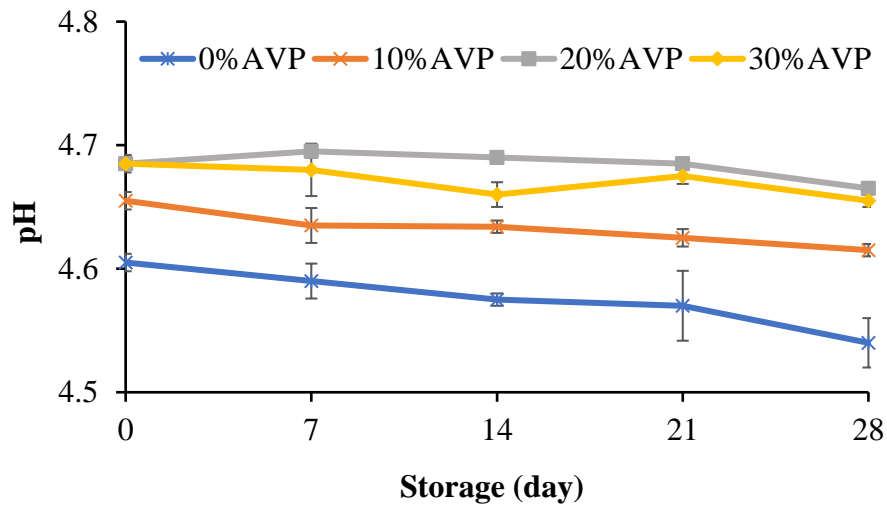
### 3.4.2 Visual Appearance and pH Measurement

The pictures of cream cheese samples prepared with and without adding avocado puree were taken after preparation, as shown in Figure 3.4, including the four samples designated as 0%AVP, 10%AVP, 20%AVP, and 30%AVP. Based on the visual observation, the characteristics of colour and texture for the cream cheese samples formulated with avocado puree at different ratios seemed significantly different by the levels of avocado puree incorporated. In terms of texture, especially, the samples with 0%AVP and 10%AVP appeared to have more creamy and smoother in appearance than the other samples containing a higher avocado content (20% and 30%AVP,) which might have been due to the fat content being lower as described in the above (Table 3.2 and Figure 3.3). In term of colour difference, it is discussed in Section 3.4.5.



**Figure 3.4 Pictures of plain cream cheese without containing avocado (0%AVP) and avocado cream cheeses incorporated with three different levels of avocado puree (10, 20, and 30% AVP).**

The pH of cream cheese samples with different levels of avocado puree was monitored during storage for four weeks at 4°C (Figure 3.5). The original cream cheese without containing avocado (0% AVP) had a pH value of 4.61, and it was decreased slightly to 4.54 after storage for four weeks. In the case of the cream cheeses containing avocado at different ratios, their pH values were observed to be slightly higher than the original plain cream cheese, which was pH 4.66-4.69 at 0 days and 4.62-4.66 after 4 weeks. Also, the pH of avocado cream cheese samples tended to be slightly higher as the ratio of avocado incorporated increased. However, the pH of these samples was not changed noticeably during storage as statistically significant differences ( $p < 0.05$ ) were not observed in pH value changes during the 28-day storage. According to Ong et al. (2020), this slight decrease of pH values during the storage in cream cheese products could be caused by the residual activity of the starter culture.

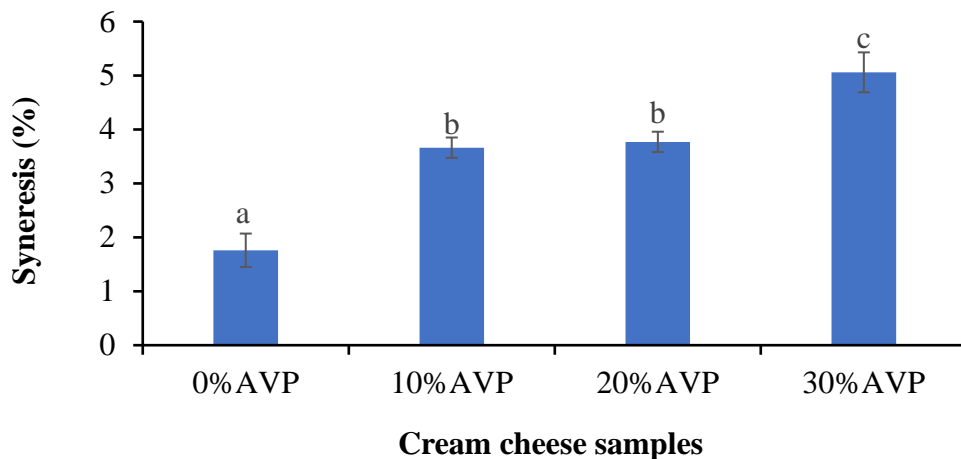


**Figure 3.5** The pH changes of cream cheese during the storage period of 28 days at 4°C (n=6).

### 3.4.3 Syneresis of Avocado Cream Cheeses

Syneresis can be defined as the serum that is escaped from the three-dimensional cheese gel structure, resulting in its separation and accumulation on the surface of the cheese. Syneresis is considered a major defect in products and is crucial in determining the quality attributes of cheese products, such as storage stability and life (Lemes et al., 2016). In this study, the syneresis of all cream cheese samples was measured after two days of storage at 4°C and expressed in a percentage which is shown in Figure 3.6. The results showed an increase in the syneresis in the cream cheeses fortified with higher concentrations of avocado puree. The cream cheese sample with 0%AVP had 1.76% syneresis, which was significantly lower than the other samples (10%AVP, 20%AVP and 30%AVP) that were measured to be 3.66, 3.77, and 5.06%, respectively. Also, the samples 10%AVP and 20%AVP had a significant difference ( $P < 0.05$ ) with the highest avocado puree concentration (30%AVP), but there was not statistically different between the two samples of 10%AVP and 20%AVP. This study showed that avocado puree concentration could lead to higher susceptibility to syneresis than the cream cheese without avocado puree. This means that a higher concentration of avocado puree caused more serum to escape from the

cream cheese. This observation could be related to differences in moisture content between the cream cheese samples in response to their protein content as discussed above and shown in Table 3.1. The relatively lower protein content in avocado-enriched cream cheese may cause a higher syneresis rate because lower protein content may not provide a stable structure and retain the moisture properly during the storage of cream cheese samples (Zulkurnain et al., 2008).



**Figure 3.6 The syneresis of cream cheese samples with and without containing avocado puree at different ratios (n=6).**

#### **3.4.4 Microbiological Safety of Avocado Cream Cheeses**

The level of some harmful microorganisms analysed in the cream cheese samples with and without avocado puree during the 28-day storage is shown in Table 3.3. All cream cheese samples were kept in sanitary vacuum-packaged pouches during the storage. Based on the results, faecal coliform was not detected in all the samples, which met the requirement of New Zealand's microbiological criteria ("Microbiological reference : criteria for food," 1995). Yeasts and moulds were absent in the cream cheeses with 0% and 10% avocado puree concentration. For 20%AVP, the total counts of yeasts and moulds were approximately 10 CFU/g on day 21 and increased to 40 CFU/g on day 28. However, 30%AVP had approximately 17 CFU/g yeasts and moulds detected on day 21 and proliferated to 60 CFU/g on day 28. This sample containing 60 CFU/g yeasts and moulds after 28 days of storage exceeded New Zealand's food safety code requirement, where the

number of yeasts and moulds should be less than 50 CFU/g. Therefore, the manufacturing process and formulations for 0%AVP, 10%AVP, and 20%AVP used were considered acceptable, which could ensure the sanitary conditions and legal microbial stability during storage for four weeks. However, as for 30%AVP, some other trials, such as the addition of preservatives, may be needed to control the microbial levels of yeasts and moulds and for more extended storage. The possible reason that a higher ratio of avocado puree added resulted in less microbial stability against yeasts and moulds is that avocado is considered as highly perishable from yeasts and moulds (Soliva-Fortuny et al., 2004). However, in this study, the yeasts and moulds counts may come from the air incorporation when mixing the different avocado puree levels with cream cheese.

**Table 3.3 The number of coliform, yeast, and mould in cream cheese samples with and without avocado puree at different concentrations were analysed during storage for 28 days at 4°C.**

Sample	Parameter	Day 0	Day 7	Day 14	Day 21	Day 28
0%AVP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	ND	ND
10%AVP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	ND	ND
20%AVP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	10 CFU/g	40 CFU/g
30%AVP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	17 CFU/g	60 CFU/g

Y & M means yeast and mould. ND means 'Not Detected'.

### 3.4.5 Colour of Avocado Cream Cheeses

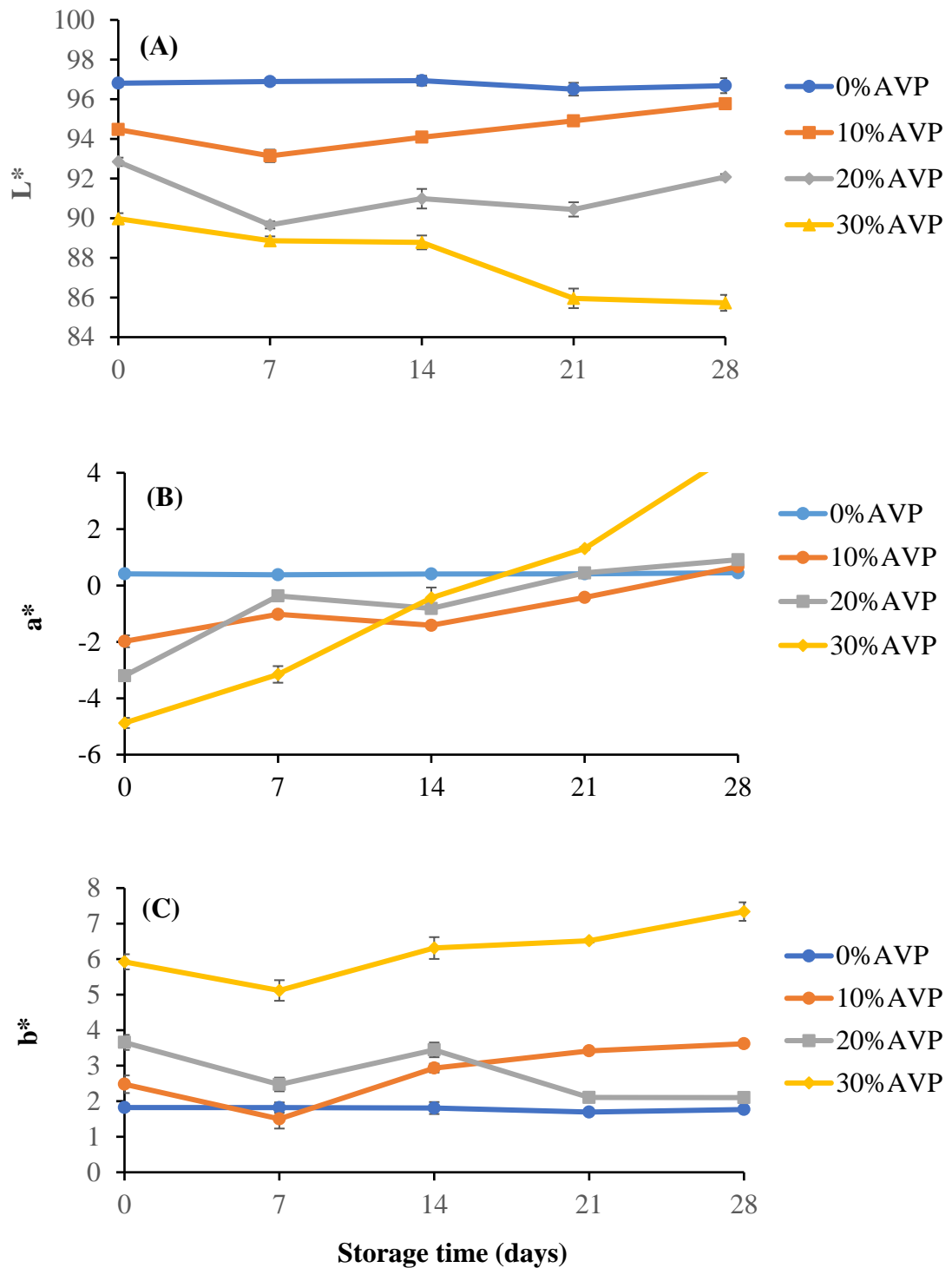
The colours of the cream cheeses with and without containing avocado puree at different ratios were monitored during storage for four weeks. The results of the colour measurement expressed in CIE L\*, a\* and b\* values, which correspond to the colour attributes of lightness/darkness, redness/greenness and yellowness/blueness, respectively, are shown in

Figure 3.7. The original cream cheese was visually pale yellowish with very weak colour saturation. This visual observation was in agreement with the  $L^*$ ,  $a^*$ ,  $b^*$  values of the sample, which were 96.81, 0.42 and 1.82, respectively. The results suggested that the original cream cheese was fairly bright in colour and had a red-yellow hue tending toward yellow, but its colour was weak (not intense), resulting in the relatively very low levels of both  $a^*$  and  $b^*$  values. In terms of colour changes during storage, the original cream cheese remained stable without noticeable colour deterioration or change for four weeks, as shown in Figure 3.7.

However, the results shown in Figure 3.7 indicate that the addition of avocado puree had a significant impact on the colour of freshly made cream cheese samples (day 0) and caused the  $L^*$  value (lightness) to decrease and the  $a^*$  (more negative, more greenness) and  $b^*$  (more positive, more yellowness) values to increase. It should also be noted that the  $a^*$  value of cream cheese was changed from positive (redness) to negative (greenness) by the addition of avocado puree, whereas the  $b^*$  value remained positive. Besides, during storage for four weeks at 4°C, the avocado puree added samples had some changes in the  $L^*$ ,  $a^*$ , and  $b^*$  values, unlike the colour of original cream cheese without containing avocado puree remained stable. For the  $L^*$  value representing lightness/darkness, the two samples with 10%AVP and 20%AVP had no pronounced changes during storage, although their lightness changes were fluctuating, especially the sample with 20%AVP. On the other hand, the sample with 30%AVP showed a significant decrease in lightness with the highest  $L^*$  decrease during storage among the samples. The value of  $L^*$  had a sharp decrease after three weeks of storage and then remained no further significant change.

In the case of the  $a^*$  value of avocado puree added samples, a significant gradual decrease (a less negative  $a^*$  value) was observed during storage from all samples containing avocado puree. The samples with 10%AVP and 20%AVP had the  $a^*$  values changed from negative (-1.98 and -3.20) to positive (0.67 and 0.92) after 4 weeks, indicating that the samples lost all greenness after 4 weeks. However, the most significant  $a^*$  value change was detected

from the sample containing the highest ratio of avocado puree (30%AVP). Its negative a\* value (-4.88) was changed to be positive (1.31 and 4.79) after 3 and 4 weeks of storage, suggesting the sample lost the greenness and changed its colour hue from green to red after the 3-week storage. This is believed to be due to the effects of enzymatic browning reaction combined with chlorophyll green pigment degradation during storage. In terms of the b\* value, the samples had a relatively small change with some fluctuations during storage compared to changes in their a\* values, but all the b\* values of all the samples remained positive (yellowness). However, it should be mentioned that the avocado cream cheese containing 30%AVP also had the most noticeable change (increase) in the b\* value during storage due to a combined effect of enzymatic browning and chlorophyll degradation.



**Figure 3.7 Changes in colours of cream cheese samples with and without containing avocado puree (0, 10, 20 and 30% AVP) during storage for four weeks at 4°C.**

Colour measurement was expressed in CIE L\*, a\*, b\* values (n=6).

In summary, the cream cheeses fortified with avocado puree (10%AVP, 20%AVP, and 30%AVP) were darker and had a more yellowish-green colour than the original plain cream

cheese sample (0%AVP). In other words, the addition of avocado puree to cream cheese causes the cream cheese product to decrease lightness ( $L^*$ ) and change the  $a^*$  value from positive (redness) to negative (greenness) with an increasing level of yellowness ( $b^*$ ) compared to the pure cream cheese sample. Besides, storage is another factor that could significantly affect the avocado-fortified cream cheese samples' (10%AVP, 20%AVP, and 30%AVP) colour stability. The higher avocado puree content could cause a higher increase rate of changes in  $a^*$  and  $b^*$  values during storage time, which could be related to the natural chlorophyll pigments that can promote the oil's photooxidation content in avocado. The produced singlet oxygen reacts with unsaturated fatty acid to form hydroperoxides which can be decomposed to initiate a free-radical autooxidation inducing avocado's colour changing (Werman & Neeman, 1986). Also, a series of avocado puree's browning reactions, as shown in Figure 2.3 in Chapter 2, could be another significant factor, forming insoluble and complex dark-coloured compounds known as melanins.

#### **Total Colour Difference ( $\Delta E^*$ )**

The difference in colour between two samples, defined as the total colour difference ( $\Delta E^*$ ) was determined by calculating the  $\Delta E^*$  values between 0 day and 7, 14 and 28 days during storage. The results are shown in Table 3.4. As for the original cream cheese sample (0%AVP), also called the control sample, the  $\Delta E$  values were very low (0.28) after four weeks of storage, which was much lower than the other samples. Thus, the colour of the control sample was best preserved and maintained without changes during the whole storage. On the other hand, among the three samples containing avocado puree at different ratios, the sample containing 10%AVP tended to be more stable in colour than the other two avocado-fortified samples with higher avocado ratios (20%AVP and 30%AVP) because their  $\Delta E$  values were much lower, being less than 2. On the other hand, the  $\Delta E^*$  values of the 20%AVP sample were all greater than three after storage of 1 week. However, no statistical difference ( $P < 0.05$ ) in the  $\Delta E$  values was observed between the samples with 20%AVP at day 7 (4.43) and day 28 (4.47). The highest colour change was observed after 28 days of storage ( $\Delta E^* = 11.28$ ) in the cream cheese sample containing 30% avocado puree

(30%AVP). Total colour change found in the 30%AVP sample could be in line with the results of its L\*, a\*, and b\* values (Figure 3.7). In summary, considering the changes of L\*, a\*, and b\* values as well as the  $\Delta E^*$  values, the cream cheese sample containing 10% AVP was relatively stable against colour change during storage compared to the other two samples (20% AVP and 30% AVP).

**Table 3.4 Changes in the total colour difference ( $\Delta E^*$ ) value observed in cream cheeses with different avocado concentrations during storage for 7, 14 and 28 days after preparation.**

Storage time (days)	0% AVP	10% AVP	20% AVP	30% AVP
7	0.23 ± 0.09 <sup>a</sup>	1.95 ± 0.63 <sup>a</sup>	3.18 ± 0.10 <sup>a</sup>	2.38 ± 0.62 <sup>a</sup>
14	0.25 ± 0.19 <sup>a</sup>	0.85 ± 0.08 <sup>b</sup>	4.43 ± 0.11 <sup>b</sup>	4.69 ± 0.41 <sup>b</sup>
28	0.28 ± 0.28 <sup>a</sup>	1.89 ± 0.04 <sup>a</sup>	4.47 ± 0.03 <sup>b</sup>	11.28 ± 0.50 <sup>c</sup>

Samples with different superscript letters within the same column show a significant difference according to Tukey's pairwise comparison ( $P < 0.05$ ).

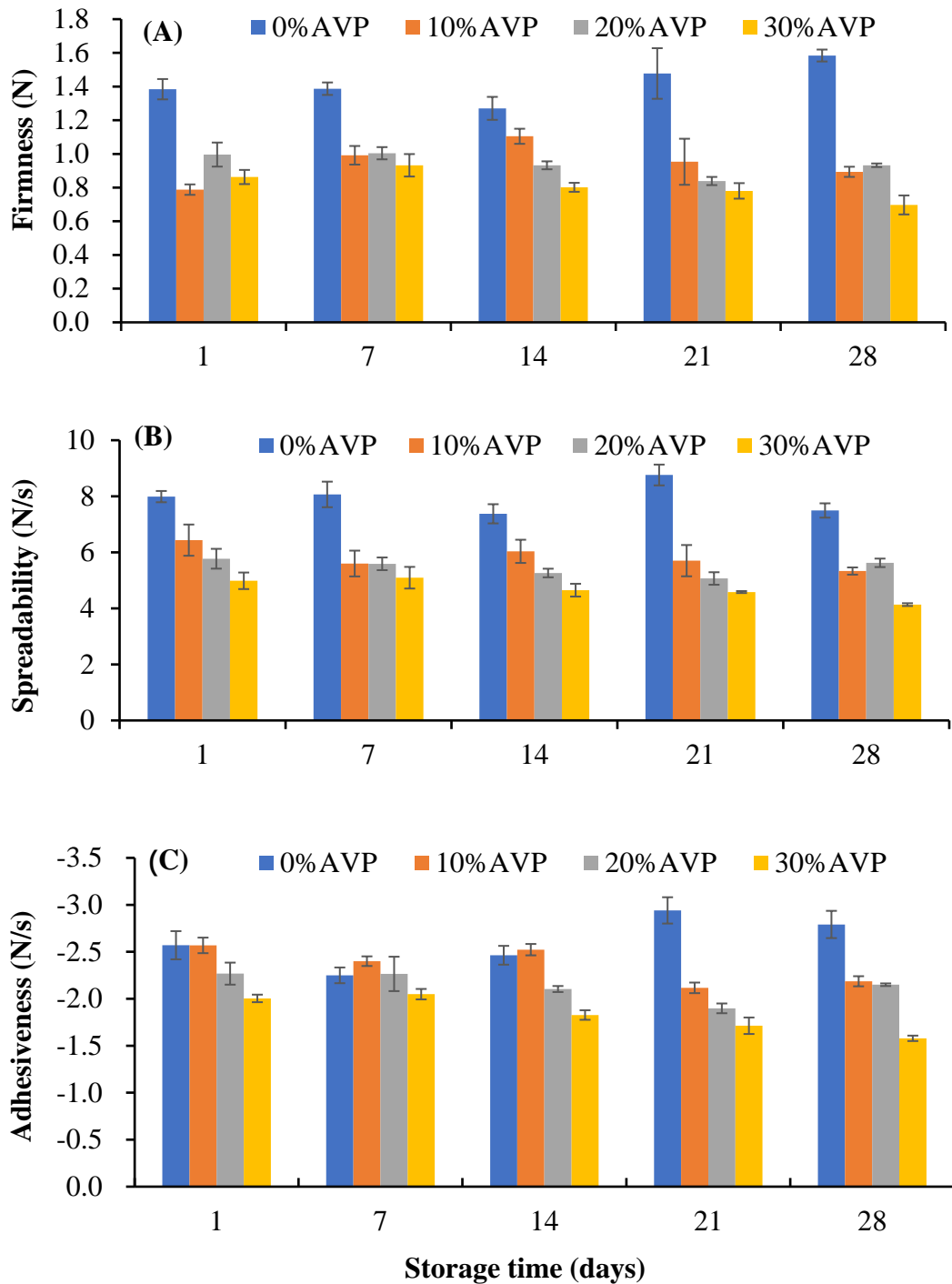
Usually, a colour difference between samples is considered visually perceptible to the human eye when the  $\Delta E^*$  value is greater than 1 under ideal viewing conditions. On the other hand, under less ideal lighting conditions, the colour difference is visually noticeable when the  $\Delta E$  value is higher than 2 (Brouillard, 1982; Francis & Clydesdale, 1975). Based on the results shown in Table 3.4, the  $\Delta E^*$  values of 20%AVP (3.18) and 30%AVP (2.38) were higher than 2 after only 1 week of storage, which means consumers would visually detect the product's colour change. Hence, adding high avocado puree (more than 10%) into cream cheese could increase colour instability during storage. These effects towards the undesirable colour changes of cream cheese products may influence consumers' purchase decisions and product acceptability. Therefore, it is necessary to process avocado puree with some chemical or physical treatments prior to its use and incorporation into cream cheese to prevent its colour degradation or enzymatic browning, thus controlling the colour change in cream cheese when fortified with high avocado puree.

### 3.4.6 Texture Profile Analysis of Cream Cheeses

The textural properties of cream cheese samples, such as firmness, spreadability and adhesiveness, were analysed from the texture profile analysis (TPA), and the results are presented in Figure 3.8. Usually, the firmness of cream cheese products could be considered as the strength of the cream cheese matrix (Ningtyas et al., 2018). As shown in Figure 3.8A, the addition of avocado puree in cream cheese significantly decreased the value of firmness. Firmness is expressed as the maximum force required for the first compression (Caner et al., 2008). Between the samples containing avocado at different ratios, overall, the firmness of cream cheese samples with more avocado puree (10%AVP, 20%AVP, and 30%AVP) seemed to be softer. However, this trend was not always consistent as shown in Figure 3.8 because the sample with 10%AVP at the beginning of storage (day 1) was measured to be slightly lower than the other samples with higher avocado ratios (20 and 30% AVP).

A possible reason for a lower firmness observed for the cream cheese samples containing avocado compared to the control sample (0%AVP) could be related to some differences in their chemical composition, as shown in Table 3.2. The control sample (0%AVP) contained more protein as well as a higher total solids content which were lower as the amount of avocado puree added was increased. Therefore, the protein gel network of cream cheeses could be weaker. In addition, the content of fat was higher in the cream cheese fortified with more avocado puree, which could inhibit the interaction between proteins (caseins) during the acid coagulation process. Also, although it is not sure, it may be partly because the size of fat globules from avocado puree was larger than the fat globules in the cream cheese due to the different methods to prepare avocado puree and cream cheese. These larger fat globules in avocado puree may decrease the cross-linking interactions between fat globules and casein particles in cream cheese, resulting in a softer texture (Lucey, 2004). As for the effect of storage time on the firmness of cream cheese samples, all cream cheese samples showed no significant differences ( $p < 0.05$ ) in firmness at different storage times, which indicated that avocado fortified cream cheese product has a stable strength profile

over the 28-day storage period at 4°C.



**Figure 3.8** Changes in firmness (A), spreadability (B) and adhesiveness (C) of cream cheese samples with avocado puree at different ratios (0, 10, 20 and 30% AVP) during storage for four weeks at 4°C.

Spreadability is used to describe how easily cream cheese products spread over a thin and even surface (Zulkurnain et al., 2008). Figure 3.8B shows that the incorporation of avocado

puree and the increase in its concentration decreased the spreadability values in cream cheese samples. The value of spreadability remarkably decreased from 7.99 N/s (0% AVP) to 4.98 N/s (30% AVP), which indicated that the higher concentration of avocado puree could make cream cheese samples less spreadable. In this study, the sample 30%AVP was the only sample with a significant difference in spreadability between day 1 and day 28 ( $P < 0.05$ ). All avocado-fortified samples showed a slight drop in the value of spreadability after storage. This may be because the cream cheese constituent's solubility (e.g. peptides, salt, and Ca) and the continuous enzymatic activities from avocado puree may cause a slight change in the spreadability during storage (Horne, 1998; Lucey et al., 2003).

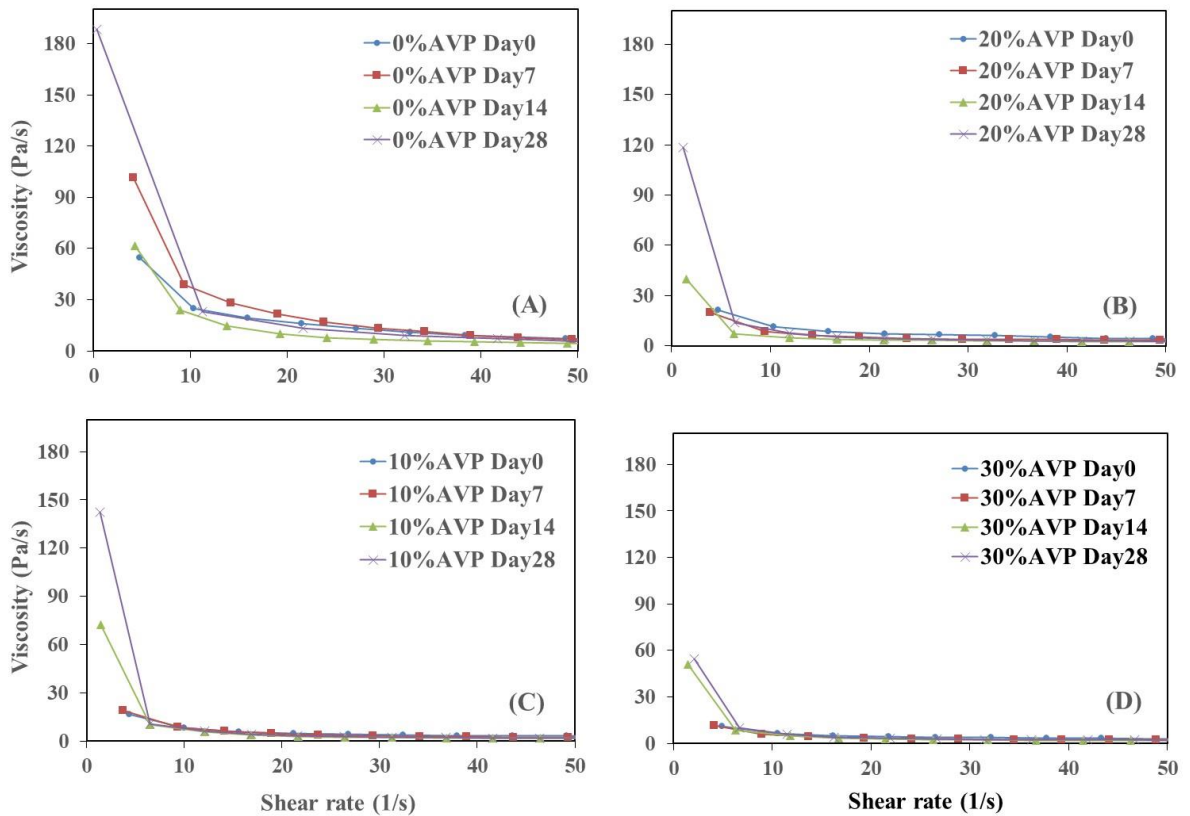
The adhesiveness value is related to the force that can help remove the cream cheese from the even surface or human tongue (Bryant et al., 1995). It was expressed as a negative force area for the work necessary to pull the compressing probe away from the sample (Pons & Fiszman, 1996). In this work, the adhesiveness value was decreased as the concentration of avocado puree increased (Figure 3.8C), demonstrating the influence of avocado puree on the adhesiveness of cream cheese. The results imply that higher concentrations of avocado puree could reduce the force needed to remove cheese products from a surface (Breidinger & Steffe, 2001). Also, adhesiveness values were stable in all samples during the whole storage, including the plain cream cheese and avocado-added cream cheeses. There was no significant difference ( $p < 0.05$ ) between adhesiveness values in different formulations from day 1 to day 28.

#### **3.4.7 Flow Behaviour of Avocado-fortified Cream Cheeses**

Figure 3.9 shows the flow curves of changes in avocado-fortified cream cheese samples' viscosity with different concentrations of avocado puree during storage. The rheological properties of cream cheese samples were analysed in terms of shear rate versus viscosity. The results show the viscosity of cream cheese was decreased by the addition of avocado puree. Also, the viscosity of all cream cheese samples produced with all levels of avocado puree was decreased when the shear rate increased and had the tendency to equalise the

viscosity, indicating that all cream cheese samples had a shear-thinning behaviour, which was also reported in many previous studies (Brighenti et al., 2018; Fox et al., 2017; Lemes et al., 2016).

The long-time refrigeration storage (4°C) might result in the higher force needed to destroy the three-dimensional structure of the cream cheese samples, which indicates that the storage time could significantly affect the rheological properties of cream cheese samples. At a low shear rate (below 20/s), the viscosity of cream samples after storage was significantly increased (Figure 3.9). However, when the shear rate was 50/s ( $\eta_{50}$ , which is relevant to oral shear), the viscosity data in Table 3.5 shows that the cream cheese samples become less viscous after storage than the fresh samples at day 0. The values of  $\eta_{50}$  in cream cheese samples produced after 28 days were lower than those of the fresh samples, which pointed out that long-term storage could make cream cheese samples less viscous around oral shear rates. These apparent viscosity results are in line with the firmness of the cream cheese samples obtained from the texture analysis of samples (Section 3.4.6), which showed a decreasing trend in the firmness of cream cheese samples during storage.



**Figure 3.9** Changes in viscosity of avocado-fortified cream cheese samples with different ratios of avocado puree (0, 10, 20 and 30% AVP) during storage for 4 weeks at 4°C.

As presented in Figure 3.9 and Table 3.5, the viscosity of cream cheeses slightly decreased with the addition of avocado puree. The values of  $\eta_{50}$  in cream cheese samples were dropped from 7.25 Pa·s (0%AVP) to 2.76 Pa·s (30%AVP) at the beginning of storage (day 0). The control cream cheese sample (0%AVP) had much higher viscosity values than the other samples containing avocado puree during the whole storage period. Notably, the level of avocado puree had a significant impact on the cream cheese's flow behaviour based on the results of this study.

However, cream cheese samples (10%AVP, 20%AVP, and 30%AVP) had no significant difference ( $P < 0.05$ ) in  $\eta_{50}$  on day 0, day 14, and day 28 (Table 3.5). This trend showed that the amounts of avocado puree added into cream cheeses at 10, 20 and 30% ratios could not significantly influence the viscosity of the cream cheeses during storage. A possible reason is that avocado puree could introduce more water in the three-dimensional network in

cream cheese, as shown in Table 3.2, and these extra moisture contents may cause the formation of a loose three-dimensional gel network and make it easier to deform the structure of cream cheese (Ningtyas et al., 2019).

**Table 3.5 The apparent viscosity ( $\eta_{50}$ ) (Pa·s) for all cream cheese samples with different avocado puree levels measured at different storage times.**

Storage time (days)	0% AVP	10% AVP	20% AVP	30% AVP
0	7.25±0.30 <sup>Aa</sup>	3.22±0.17 <sup>Ab</sup>	3.85±0.48 <sup>Ab</sup>	2.76±0.37 <sup>Ab</sup>
7	7.61±1.26 <sup>Aa</sup>	2.65±0.33 <sup>ABb</sup>	2.27±0.36 <sup>ABb</sup>	2.15±0.11 <sup>Ab</sup>
14	5.65±1.51 <sup>Aa</sup>	1.83±0.18 <sup>Bb</sup>	2.32±0.01 <sup>ABb</sup>	1.95±0.24 <sup>Ab</sup>
28	4.91±0.79 <sup>Aa</sup>	2.07±0.34 <sup>Bb</sup>	2.26±0.47 <sup>Bb</sup>	1.92±0.18 <sup>Ab</sup>

<sup>A, B</sup> Within a column, different superscript capital letters denote significant differences ( $p < 0.05$ ) different types of cream cheese on the same days of storage.

<sup>a, b</sup> Within a row, different lowercase superscripts denote significant differences ( $p < 0.05$ ) between different days of storage for each type of cream cheese.

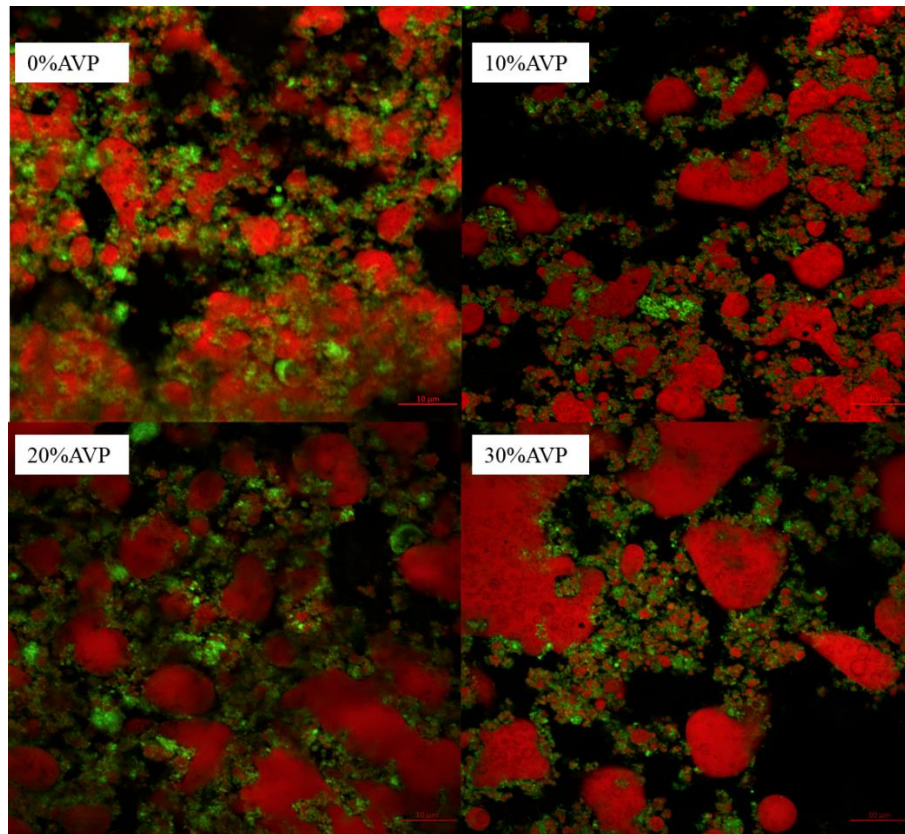
### 3.4.8 Microstructure of Avocado-fortified Cream Cheeses

The microstructural features of the avocado-fortified cream cheese samples were analysed using confocal laser scanning microscopy (CLSM). The CLSM images are shown in Figure 3.10. The CLSM may provide a detailed insight into the interaction between protein and fat in cream cheese samples and the size and distribution of fat globules in relation to the sample formulations. Figure 3.10 illustrates that avocado puree did not significantly affect the microstructure of cream cheese by showing the discontinuous protein network stained in green and fat stained in red. The microstructure of the cream cheese fortified with different levels of avocado puree observed in this study was similar, to some extent, to the CLSM analysis of a typical cream cheese product from a study reported by Wendin et al. (2000). Cream cheese is structurally different from other cheeses because it does not have a compact protein matrix network and has high fat and moisture content (Macdougall et al., 2019; Ong et al., 2011; Wendin et al., 2000). As a result, the microstructure of cream cheese is typically defined as corpuscular, which means its structure is composed of compact

protein (casein) and fat aggregates in which large spaces are filled with whey (Macdougall et al., 2019; Wendin et al., 2000).

Based on the images shown in Figure 3.10, the fat globules in all avocado-fortified cream cheese samples appeared to be centrally located in the corpuscular clusters, and the protein tended to aggregate at the surface of this structure and formed an interface between the aqueous and lipid phases of the cream cheese samples, which is similar to the findings of Kalab et al. (1981). Also, Figure 3.10 shows many relatively large fat globules dispersed among the corpuscular aggregates in all cream cheese samples containing different concentrations of avocado puree. According to Lenze et al. (2019), these fat globules may arise from the de-emulsification of fat in the final stages of sample processing, which may cause the coalescence of fat globules (Kalab et al., 1981). However, in this study, the addition of avocado puree did not seem to affect the structure and size of these fat globules significantly.

The unstained black area is another microstructural feature indicating the serum phase in the microstructure of samples (Fenoul et al., 2008), which contains water and various solutes, including salt, stabilisers and carbohydrates. The area of cream cheese's serum phase depended on the moisture content level in the samples, and it would tend to be more prominent in samples having a high-water content (Macdougall et al., 2019). As shown in Figure 3.10, the cream cheese samples containing avocado puree (10%AVP, 20%AVP, and 30%AVP) appeared to have larger serum phase areas than the control sample (0%AVP) because of their higher water content, as shown in Table 3.2. Consequently, the samples fortified with more avocado puree seemed to result in a larger black area, which indicates that avocado puree introduced more moisture content into the cream cheese sample. This was in line with the results from the analysis of chemical composition as described in Section 3.4.1 of this chapter.



**Figure 3.10 Microstructures of cream cheese samples containing different concentrations of avocado puree (0, 10, 20 and 30% AVP) were determined by CLSM imaging.**

Fat, protein and serum phases appear red, green, and black, respectively.

### **3.4.9 Sensory Evaluation**

The sensory evaluation of avocado cream cheese samples was conducted as described in the Materials and Methods section, but the results are discussed in more detail in Chapter 5. Briefly, there were 37 panellists invited to take the sensory test at a local net cafeteria (HTC Net café, Albany, New Zealand). Participants were offered freshly made cream cheeses fortified with different concentrations of avocado puree (0%AVP, 10%AVP, 20%AVP, and 30%AVP). According to the results from the sensory test, 41% of participants thought that the cream cheese containing 20% (w/w) avocado puree was the best-tasted sample in all cream cheese samples offered. Other detailed information is comprehensively analysed and discussed in Chapter 5.

### 3.5 Conclusions

The novel cream cheese product containing different concentrations of avocado puree showed some significant changes in quality and stability parameters. The addition of avocado puree caused an increase in the moisture, fat, and ash contents into cream cheese products, which resulted in a series of effects on the cream cheese's quality, such as higher syneresis and lower viscosity. Avocado puree decreased the firmness and spreadability of cream cheese, and however, the samples containing 10%AVP and 20%AVP had stable firmness and spreadability qualities during storage, indicating a stable texture profile. Also, the rheological studies demonstrated that the cream cheeses containing avocado puree exhibited a shear thinning behaviour as regular cream cheese products but were less viscous. However, in terms of colour, the avocado-fortified cream cheese samples exhibited some changes in their colour during storage. The higher concentration of avocado puree resulted in a more significant colour change of cream cheese during storage. In microbiological tests, introducing more avocado puree into cream cheese was found to affect microbiological safety by increasing more yeast and mould strains which were found after storage for 3 weeks at 4°C.

Therefore, considering consumers acceptability from the sensory evaluation and stability of the cream cheeses, one product with medium avocado puree contents could be suggested for further development, the cream cheese with a 20% (w/w) concentration of avocado puree (20%AVP). Avocado puree is added as a functional ingredient to improve the nutritional value of cream cheese and a new fruit flavour of cream cheese, so adding 10% (w/w) avocado puree may not be enough to achieve the goal. Also, too much avocado content, such as 30% avocado puree (30% AVP), could significantly affect the quality and stability of the cream cheese. Importantly, consumers may be more likely to choose a cream cheese product with the addition of 20% (w/w) avocado puree. Thus, 20% (w/w) avocado puree would be considered an ideal level concentration that may benefit consumers' acceptability and quality. However, this study also indicated that even a tiny amount of added avocado puree could affect the quality and stability of cream cheese, especially

colour. Hence, a future study about the further processing of avocado puree is necessary to minimise its influence.

## **Chapter 4. Treatments of Avocado Puree with HPP or Ascorbic acid: Its Effects on the Properties and Stability of Avocado-fortified Cream Cheeses during Storage**

### **4.1 Abstract**

The consumers demand for healthy dairy products has been growing steadily, which indicates the necessity to develop new products or improve existing products to meet consumers' requirements. This study aimed to improve the colour stability of a novel cream cheese product enriched with 20% (w/w) avocado puree that was treated by three different methods and investigate their effects on the product's quality and stability parameters during a 28-day storage period at 4°C. Three different treatments applied to avocado puree were: i) ascorbic acid addition, ii) high-pressure processing (HPP) treatment, and iii) HPP-treatment in combination with ascorbic acid addition. Also, untreated (UT) avocado puree was used as the control. The cream cheese within HPP-treated avocado puree containing ascorbic acid as an antioxidant was found as a suitable method based on this study, which had less syneresis and better colour protection. Texture profile analysis (TPA) indicated that the three different avocado puree treatments used had no significant difference in the textural properties (firmness, spreadability, and adhesiveness) between the samples. The cream cheese containing treated avocado puree had a better microbiological safety, in terms of the total yeast and mould count during storage, compared to the control sample containing untreated avocado puree. However, in terms of colour change, the cream cheeses with untreated avocado puree and HPP-treated avocado puree were more sensitive to the colour change and degradation compared to the other cream cheeses containing ascorbic acid-treated puree. The results in this study showed that HPP-treated avocado puree with added ascorbic acid improved the quality and stability of cream cheese fortified with 20% avocado puree without significantly changing the overall features of cream cheese.

### **4.2 Introduction**

Cream cheese is defined as a fresh cheese with a smooth creamy texture and flavour produced from a mixture of milk and cream by acid-coagulation of milk proteins (caseins)

(Collins & Senge, 2004; Parente et al., 2017). This product is usually used as a spread for crackers and bagels or as a dip for snacks and chips (Brighenti et al., 2008). Some health-conscious consumers may not want to purchase cream cheese products because of their relatively high-fat content (Apilado et al., 2013). Therefore, some studies have been conducted to develop new types of cream cheese products (e.g., combining cream cheese with organogels prepared with vegetable oils) to make it relatively healthier, thus being readily acceptable to consumers (Bahrami et al., 2015; Bemer et al., 2016; Limanowski, 2016).

Avocado (*Persea americana*) can be regarded as a workable fruit mixed with cream cheese to make a value-added cream cheese as a novel product with health and nutritional benefits. Avocado fruit is high in protein and contains more fat-soluble vitamins than other fruits, such as vitamins A, D and E (Ashton, 2005). Avocado is also a good source of several other essential lipid compounds, such as monounsaturated fatty acids (MUFA), squalene and phytosterols (Ding et al., 2007; Santos et al., 2014).

However, fresh-cut avocados usually rapidly deteriorate due to microbial, chemical and physical actions (Bustos et al., 2015). Thus, it is spoiled readily, resulting in a short shelf-stability (Yahia & Gonzalez-Aguilar, 1998). The shelf-life of avocado pulp is about two days which is much shorter than the entire fruit (about five days) at ambient temperature due to its oxidative degradation, such as lipid oxidation and enzymatic browning (Balda et al., 2011). Avocado's enzymatic browning during its processing and storage is one of the crucial factors that adversely affects the shelf life. This quality decay from the oxidative enzymatic browning reaction mainly occurs in the aqueous fraction where phenolic substrates are hydroxylated and oxidised, leading to the brown pigments known as melanins (Robards et al., 1999).

Many different chemical and physical agents have been used in research studies to prevent enzymatic browning and extend shelf stability without affecting avocado's sensory and

quality attributes. For example, ascorbic acid is a powerful antioxidant that is water soluble, thus working in the aqueous fraction of avocado to prevent enzymatic browning reactions (Soliva et al., 2000). In a study reported by Bustos et al. (2015), avocado pulps added with ascorbic acid had a better anti-browning property, and the colour of avocado was preserved up to 30 days during storage at 4°C. Ascorbic acid as a reducing agent reduces the o-quinones generated from the oxidation of phenolic compounds to catechol, thus inhibiting quinones' polymerisation reaction to form melanins, slowing down the enzymatic browning reaction (Hsu et al., 1988).

On the other hand, consumer demand for minimally processed food products have increasingly risen from the 1990s (Hoover, 1997). As such, many new technologies have been gradually applied in the food industry. High-pressure processing (HPP) is an emerging technology that has gained increasing attention in the food industry (Torres & Velazquez, 2005). HPP can bring numerous benefits to foods, such as reducing microbial counts and inactivating enzymes, with minimal effects on food product's flavour and colour (Ludikhuyze et al., 2002). As for avocado-related products, HPP treatment has been proved to lengthen the shelf life and influence the endogenous enzyme activity in avocado-related products, including avocado paste and slices (Jacobo Velazquez & Hernandez Brenes, 2010; Ludikhuyze et al., 2002; Malo et al., 1998). It has been reported that HPP can reduce polyphenol oxidase (PPO) activity inside the avocado, which is an enzyme that catalyses the enzymatic browning reaction involving the oxidation of phenolic compounds to form quinones. Specifically, the residual PPO activity in guacamole, a pureed or mashed avocado seasoned with condiments, was reduced 49% after a five-minute HPP treatment at 689 MPa (Palou, Hernández-Salgado, et al., 2000). Similarly, Velazquez et al. (2010) also found that the residual PPO activity was reduced to 51%, and lipoxygenase (LOX) activity, an enzyme catalysing lipid oxidation, was reduced to 55% in avocado paste after 600 MPa treatment for 3 minutes.

However, there are very few literatures available on the different treatments of avocado

purees for their use and incorporation into cream cheeses, Also, to the best of my knowledge, avocado-fortified cream cheese product is not commercially available in the market. Therefore, this study will help develop a novel product which can fill a gap in the market. The objective of this study was to find the effects of avocado puree treated by several methods on the quality and stability of cream cheeses fortified with avocado puree (20% w/w) during storage. The content of avocado puree added into cream cheese as 20% was based on the previous results as shown and discussed in Chapter 4. Briefly, incorporating avocado puree at 20% was reasonably suitable in terms of product stability and consumer acceptability. Avocado-fortified cream cheese samples were analysed for their colour stability, textural and rheological properties and microbiological safety.

### **4.3 Materials and Methods**

#### **4.3.1 Materials**

This study obtained ascorbic acid from a local ingredient supplier (Hawkins Watts Limited, New Zealand) and added to avocado puree as a reducing agent. Other ingredients (e.g. whole milk, Half & Half milk, sea salt, garlic powder, cheese culture, rennet, LBG, and avocados) used in manufacturing avocado cream cheese samples were the same as described in Section 3.3.1 in Chapter 3.

#### **4.3.2 Preparation of cream cheese**

Cream cheese was prepared using the same method as described in Section 3.3.2 in Chapter 3, which was based on the methods reported by Ningtyas et al. (2018) and Phadungath (2005) with some modifications.

#### **4.3.3 HPP treatment of avocado**

As described in Section 3.3.3 in Chapter 3, the fresh ripen avocados purchased from a local supermarket (PAK'nSAVE, New Zealand) were cut into halves lengthwise using a knife. After removing seeds and skin, the avocado flesh halves were vacuum packaged using a vacuum packaging machine (Type-C300, MULTIVAC, Germany) and stored at -20°C until

utilised. Some the avocado halves were taken to the NZ Food Innovation Auckland Ltd. (New Zealand), where the avocado halves were treated at 20°C by HPP (55 L HPP unit, Uhde High-Pressure Technologies, Germany) at 600 MPa for 10 minutes for enzyme PPO inactivation. The HPP unit used in this study is shown in Figure 4.1. After the HPP treatment, the HPP treated samples were stored in an ice bath (0-4°C) and transferred to the product development (PD) lab at Massey University (Auckland, New Zealand) and stored at -20°C until use.



**Figure 4.1 High-pressure processing (HPP) unit used in this project to treat avocado halves to inactivate PPO enzyme.**

#### **4.3.4 Preparation of cream cheeses containing differently treated avocado purees**

After thawing the frozen avocado halves at 4°C overnight, the defrosted avocado halves, such as untreated and HPP-treated avocado halves, were used to prepare the avocado puree. Briefly, avocado halves were grounded in a sanitised small stainless bowl and homogenised into puree by a hand mixer (Living & Co 250W Stick Mixer, New Zealand). After homogenising, a portion of avocado purees (untreated and HPP-treated avocado puree) was added with 2% w/w ascorbic acid as a reducing agent to prevent enzymatic browning and then mixed with cream cheese (20:80 w/w ratio). A hand mixer was used to uniformly blend the mix of avocado puree and cream cheese. The cream cheese samples prepared after mixing with 20% w/w of differently treated avocado purees were designated by sample

codes as UT, ASC, HPP and AHPP (Table 4.1).

**Table 4.1 Sample codes of cream cheese samples after mixing with 20% avocado puree which was treated or untreated.**

<b>Sample codes</b>	<b>Avocado</b>	<b>Avocado puree</b>	<b>Cream cheese</b>
<b>UT</b>	20%	No treatment	80%
<b>ASC</b>	20%	Ascorbic acid	80%
<b>HPP</b>	20%	HPP	80%
<b>AHPP</b>	20%	HPP and Ascorbic acid	80%

#### **4.3.5 Analysis of Samples**

Cream cheese samples containing avocado puree were analysed in several aspects, such as pH value, colour change, rheological properties, textural properties, microstructural features, syneresis and microbial analysis, as described in Sections 3.4 in Chapter 3. All samples were analysed after preparation and during storage at 4°C at 0, 7, 14, 21 and 28 days. Moreover, a comprehensive sensory evaluation was also conducted, but the results are described in Chapter 5, with another group of samples formulated based on the analysis results of samples described in this chapter.

#### **4.3.6 Data Analysis**

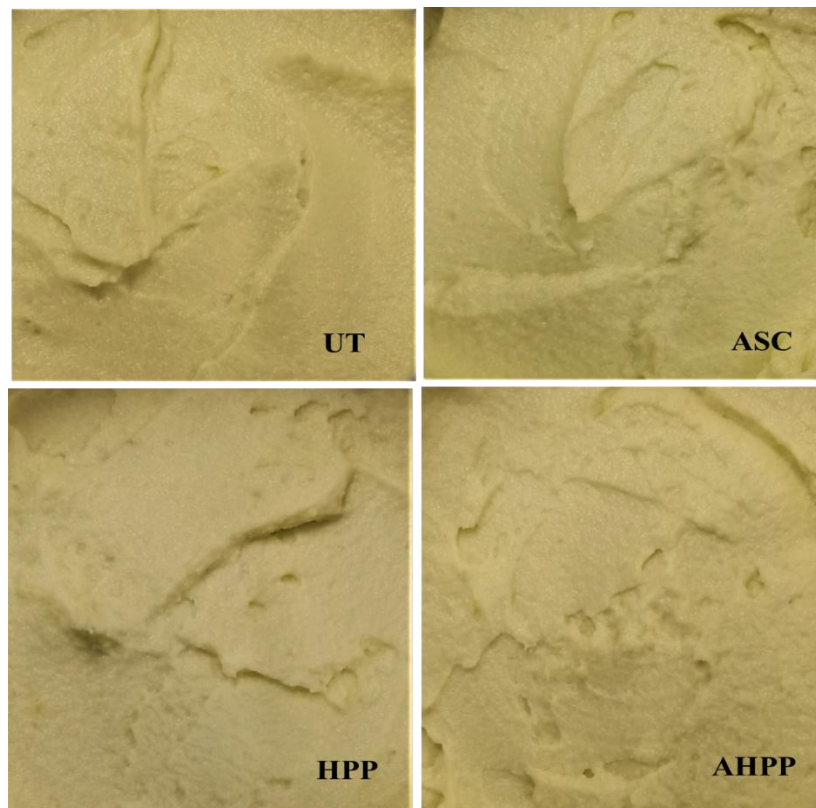
All measurements in this study (pH values, colour, viscosity, textural analysis, syneresis, and microbiological analysis) were conducted at least in duplicate for each sample from duplicate experiments. All data were analysed in the Minitab Statistical Software (Minitab 19 Statistical Software, USA). The one-way analysis of variance (ANOVA) was applied to analyse the differences between samples' mean values at a significance level of  $p < 0.05$ .

### **4.4 Results and Discussions**

#### **4.4.1 Appearance and pH of cream cheeses**

The cream cheese samples were prepared by mixing with differently treated avocado purees (UT, ASC, HPP, and AHPP), as shown in Table 4.1. The pictures of these samples taken after preparation before storage are shown in Figure 4.2. The colours of all cream cheese

samples were visually similar, regardless of the different methods of avocado puree treatment. However, the textural appearance of cream cheese samples seemed to be visually different according to the different treatments of avocado puree. Specifically, HPP and AHPP samples visually appeared to be slightly grittier, indicating that the HPP treatment might have affected the texture of avocado puree, so it influenced the resulting cream cheese. This visual outcome was in line with the findings of Section 4.4.5 (Texture profile) in this chapter, which showed that the firmness and spreadability of cream cheeses with the HPP-treated avocados (HPP and AHPP) were lower than the other samples (UT and ASC).

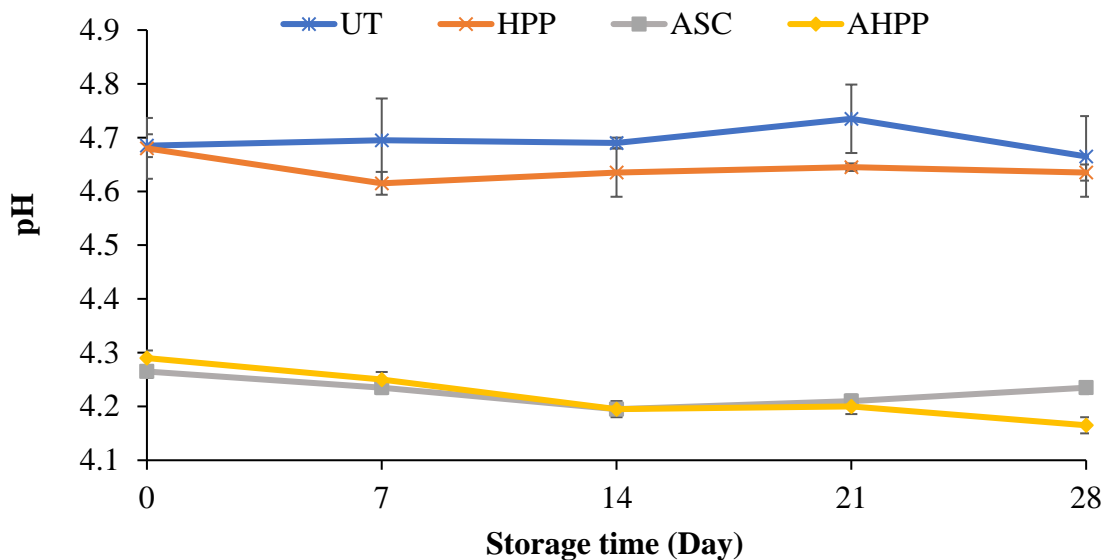


**Figure 4.2 Pictures of cream cheese samples containing 20% (w/w) avocado puree. Avocado puree was treated with HPP or ascorbic acid (ASC) before mixing with cream cheese.**

UT: no treatment, ASC: ascorbic acid, HPP: high-pressure processing and AHPP: HPP and ascorbic acid.

The pH values of cream cheeses fortified with avocado puree treated by different methods measured during storage for 4 weeks are shown in Figure 4.3. Cream cheese samples (ASC

and AHPP) containing ascorbic acid-treated avocado puree showed a slightly lower pH value of around 4.26 than the other samples (UT and HPP), with a pH value of 4.68. This was because ascorbic acid is a weak acid meaning mildly acidic (Hsu et al., 1988; Pizzocaro et al., 1993), thus lowering the pH slightly. In terms of the pH change during storage, all samples seemed to be stable, although the pH of cream cheese sample containing avocado puree treated with both HPP and ascorbic acid seemed to decrease slightly during storage, no statistically significant difference was observed during the 28-day storage. Therefore, it can be concluded that the pH values of all cream cheese samples were stable during the storage.

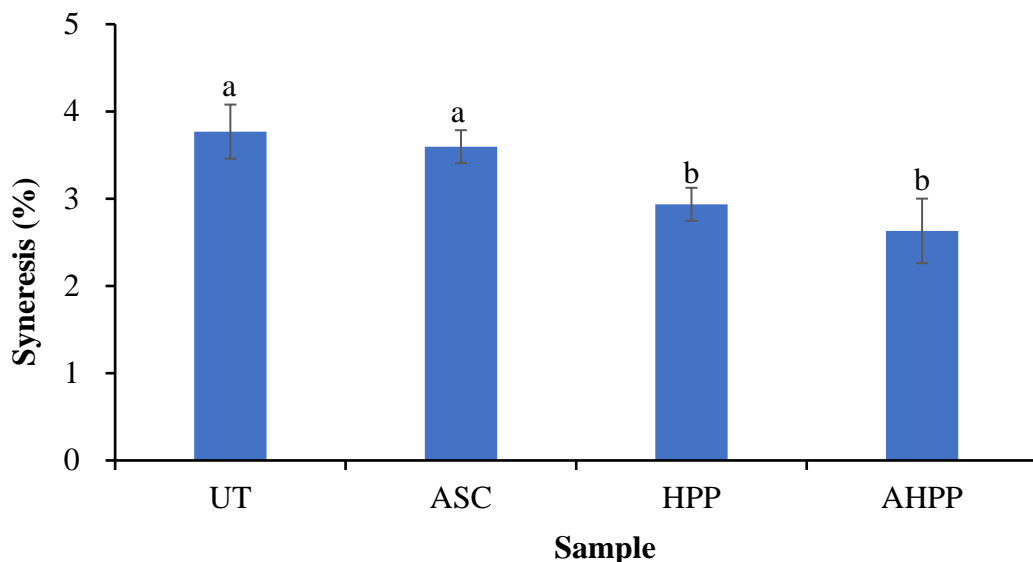


**Figure 4.3** The pH changes of cream cheeses with a concentration of 20% avocado puree treated by different methods (UT, HPP, ASC and AHPP) during the storage period of 28 days.

#### 4.4.2 Syneresis Measurement

The susceptibility of avocado-fortified cream cheese samples to syneresis was measured using centrifugation and expressed as a percentage of serum separated from the cream cheese matrix. This means the serum escaped from the gel structure of cream cheese and accumulated on the surface of cream cheese (Lemes et al., 2016). It is one of the essential

parameters being widely measured from some dairy products (e.g. cream cheese, yoghurt, etc.) to determine their quality and stability attributes. As shown in Figure 4.4, syneresis was found to be slightly higher in the samples designated as UT and ASC than the HPP and AHPP samples. This means that the cream cheese sample with HPP-treated avocado puree had relatively minor syneresis than the other two samples containing avocado puree that was not treated with HPP. The other cream cheese sample (AHPP) with avocado puree treated by both HPP and ascorbic acid had the least syneresis value (2.63%) among all samples tested in this study. This result showed that the HPP treatment of avocado puree led to a lower syneresis in cream cheese.



**Figure 4.4 Syneresis (%) of cream cheeses with differently treated avocado puree measured by a centrifugation method.**

#### 4.4.3 Microbiological Safety

The level of some harmful microorganisms in the cream cheese samples with treated and untreated avocado purees during the 28-day storage at 4°C is shown in Table 4.2. All the avocado-fortified cream cheese samples were stored in a clean and sanitary condition. Based on the results in Table 4.2, faecal coliform was not detected in all samples. Yeast and mould were absent in all cream cheese samples, too, during storage, except for some samples, such as UT (day 21 and 28), HPP (day 28) and AHPP (day 28). Although it is not sure, a slightly lower pH induced by ascorbic acid might have affected the inhibition of

yeast and mould as the growth of yeast and mould was detected only in the sample (ASC) containing ascorbic acid-treated avocado puree during the entire storage period of 28 days. For the UT sample (control sample) containing untreated avocado puree, the total yeast and mould count was approximately 10 CFU/g on day 21 and increased to 40 CFU/g on day 28. However, for the cream cheese with HPP-treated avocado puree, it was approximately 20 CFU/g in the final week of storage, indicating the HPP treatment used in this study might not have been very effective in inactivating yeasts and moulds, which was in line with the previous studies reported by some researchers (Goh et al., 2007; Hashizume et al., 1995; Sulaiman et al., 2015).

**Table 4.2 The number of coliforms, yeast, and mould in cream cheese samples with differently treated avocado puree.**

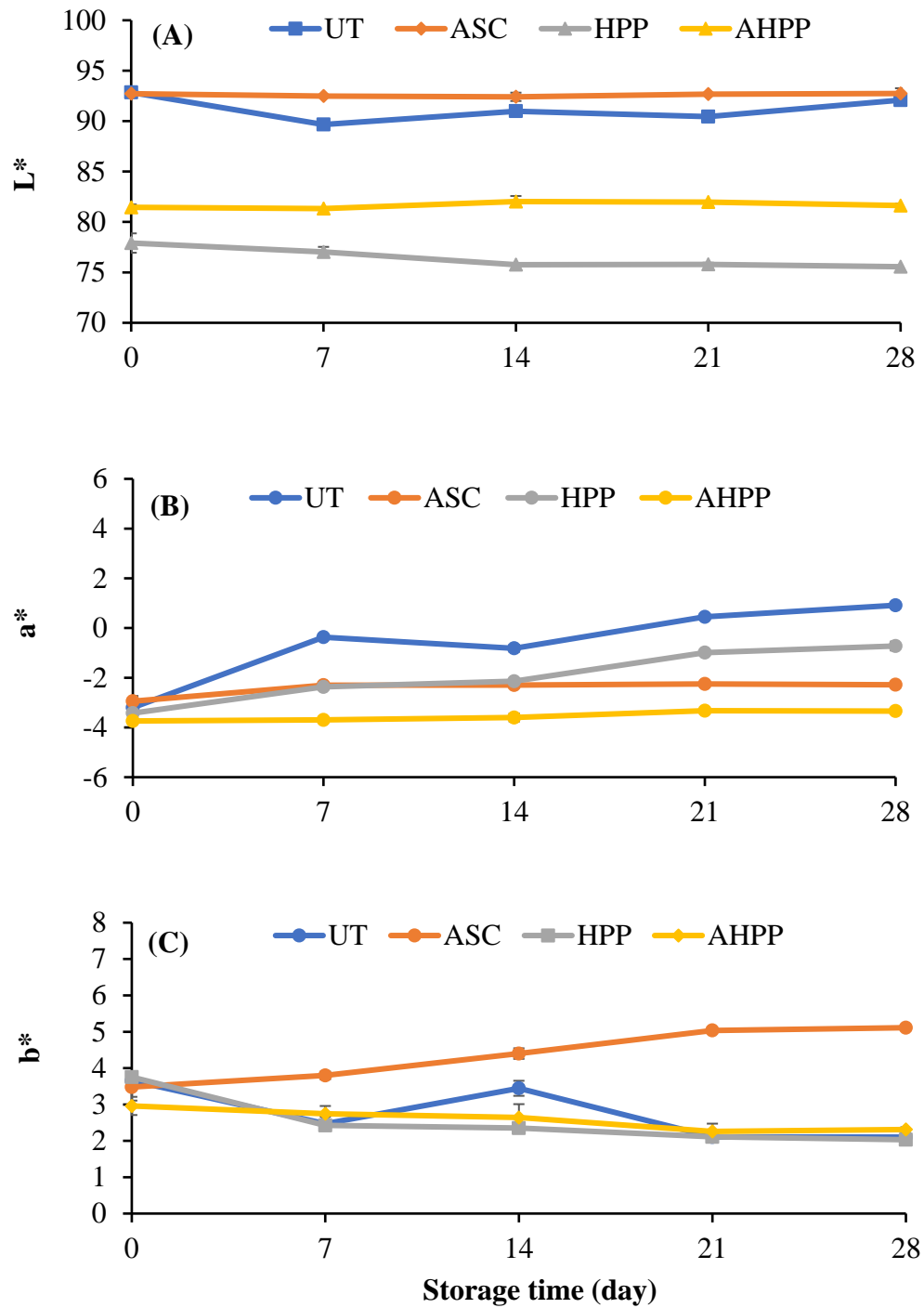
Sample	Parameter	Day 0	Day 7	Day 14	Day 21	Day 28
UT	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	10 CFU/g	40 CFU/g
ASC	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	ND	ND
HPP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	ND	20 CFU/g
AHPP	Coliform	ND	ND	ND	ND	ND
	Y & M	ND	ND	ND	ND	10 CFU/g

Y & M represents yeast and mould. ND means “not detected”.

#### 4.4.4 Changes in Colour during Storage

The CIE L\*, a\* and b\* values of cream cheese samples, representing lightness (L\*), redness (a\* if positive)/greenness (a\* if negative), and yellowness (b\* if positive)/blueness (b\* if negative), were measured and used to determine the change of colours in avocado-fortified cream cheese samples as shown in Figure 4.5. It was found that the HPP treatment on avocado puree could significantly decrease the value of lightness (L\*) in its corresponding cream cheese samples (HPP and AHPP) (Figure 4.5A on day 0). The L\* values for the

cream cheese samples with the HPP and AHPP treated avocado purees were 77.91 and 81.45, respectively, at day 0. In contrast, the L\* values for the samples containing the UT or ASC avocado purees were higher, being 92.84 and 92.08, respectively. As for the effect of treatments during storage, overall, all cream cheese samples, regardless of the type of treatments used in this study, tended to have stable L\* values without a significant change during the 4-week storage, although the lightness values of the UT sample had some fluctuation.



**Figure 4.5 Changes in colour (CIE L\*, a\* and b\* values) of cream cheese samples fortified with avocado puree with different treatments (UT, ASC, HPP, AHPP) during storage at 4°C for 4 weeks (n=6).**

In terms of a\* value, the a\* values of all samples measured at 0 days were negative, indicating the samples had a green colour hue. However, the greenness (-a\*) did not show a significant difference between all samples at the beginning of storage (day 0) as shown in

Figure 4.5B. The green colour hue was attributable to the avocado puree added into all cream cheese samples at the concentration of 20%, which was the primary source of the green colour. However, different treatments applied on the  $a^*$  value of cream cheese samples was significant during storage. The  $a^*$  values of cream cheese samples containing untreated avocado puree (UT) had the most significant change during storage. The negative  $a^*$  value (-3.20) of the UT sample was sharply decreased (less negative  $a^*$ ) during storage and then changed to the positive  $a^*$  values of 0.45 and 0.92, respectively, after 21 and 28 days, which was close to 0, suggesting a loss of greenness. Also, for the HPP-treated avocado-fortified cream cheese sample without adding ascorbic acid, its negative  $a^*$  value (-3.42) at day 0 was gradually decreased (less negative) during the storage resulting in the  $a^*$  value of -0.99 and -0.72, respectively, after the storage for 21 and 28 days. The loss of greenness in these two samples could partly result from an enzymatic browning that might have occurred in these two samples, suggesting the HPP treatment alone used in this study might not have been effective in fully inhibiting the activity of the activity enzyme PPO present in avocado. The above results obtained were in agreement with the findings of González-Cebrino et al. (2016) from a study with pure pumpkin puree. They showed that HPP could not be efficient enough to reduce the residual PPO activity and delay the browning so that the original colour of the pumpkin puree could not be maintained. However, notably, the  $a^*$  values of ascorbic acid-treated samples, including ASC sample and AHPP sample, were relatively stable without changes during storage than the other samples (UT and HPP). This result clearly indicated that ascorbic acid could preserve the original green colour hue of cream cheese samples fortified with avocado puree for at least 28 days at 4°C. This result also suggested that ascorbic acid was effective in controlling the enzymatic browning and maintaining the green colour hue of avocado-fortified cream cheese samples.

As for the  $b^*$  values, Figure 4.5C shows that all samples had positive  $b^*$  values, ranging from 2.03 to 3.66 at day 0, indicating the samples had yellowness in colour. The  $b^*$  values of samples (UT, HPP, and AHPP) had a similar trend during storage with a slight decrease.

On the other hand, the cream cheese sample (ASC) containing avocado treated only with ascorbic acid without HPP had a slight increase in its  $b^*$  value during storage which was somewhat unexpected, unlike its  $a^*$  value remained steady without change during storage as discussed above.

In summary, ascorbic acid showed a significant effect in maintaining lightness ( $L^*$ ) and greenness ( $-a^*$  value) in cream cheese fortified with 20% avocado puree, but yellowness ( $+b^*$  value) had some increase during storage in this study. Nevertheless, ascorbic acid could still be an influential factor that led to the colour protection of cream cheese containing 20% avocado puree compared to the other treatments used in this study. It should also be mentioned that adding ascorbic acid into the HPP-treated avocado puree (AHPP) was the most effective way to protect the colour of avocado-fortified cream cheese, which showed a relatively minimal change in  $L^*$ ,  $a^*$ , and  $b^*$  values during storage in this study.

#### **Total Colour Difference ( $\Delta E^*$ )**

Changes in the total colour difference ( $\Delta E^*$ ) within the same samples during storage after 7, 14 and 28 days were determined from the results of CIE  $L^*$ ,  $a^*$  and  $b^*$  values via mathematical calculations. The  $\Delta E$  value indicates the overall difference between two colours. The  $\Delta E$  values calculated are shown in Table 4.3, which indicate the effect of different treatments of avocado puree had a significant impact on the overall colour difference between samples. As anticipated based on the results of  $L^*$ ,  $a^*$  and  $b^*$  values (Figure 4.5) above, a significantly higher value of  $\Delta E$  during storage was observed from the two samples (UT and HPP) ( $p < 0.05$ ), that is, the cream cheese samples containing untreated avocado or avocado treated with HPP only. This outcome agreed with findings previously reported by Palou et al. (1999), which showed that HPP might not be a highly effective method for controlling browning reactions. As for the cream cheese samples containing ascorbic acid-treated avocado (ASC and AHPP), their colour was better preserved and maintained during the whole storage period than the other samples (UT and HPP).

According to Francis and Clydesdale (1975), when the  $\Delta E^*$  value was higher than 2, the measured colour change could be considered visually noticeable for consumers. Based on the results shown in Table 4.3, both UT and HPP samples could be visually detected in colour change ( $\Delta E > 2$ ) after 7-day storage. Ascorbic acid treatment, including ASC and AHPP samples, could reduce browning reactions in avocado puree and ensure the colour change not visually noticeable. However, the value of  $\Delta E^*$  in ASC samples reached 1.82 after 28 days of storage, and AHPP's  $\Delta E$  value (1.31) was slightly lower than ASC. Thus, adding ascorbic acid in HPP-treated avocado puree seemed to be the most effective treatment for reducing the sample's colour change in this study.

**Table 4.3 Total colour difference ( $\Delta E^*$ ) values for cream cheese samples containing avocado puree with different treatments (UT, ASC, HPP and AHPP) calculated during storage at 7, 14 and 28 days.**

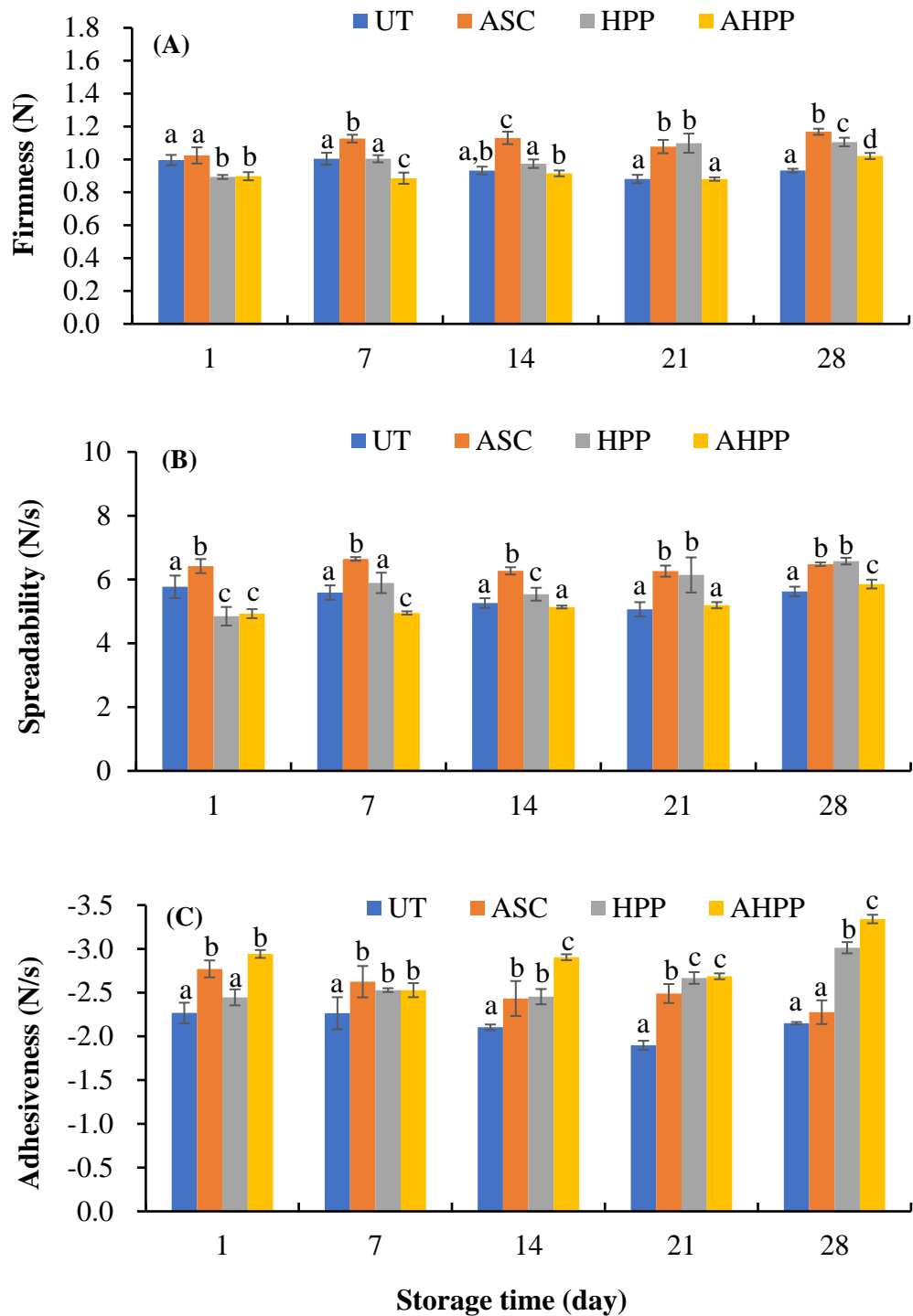
Storage (day)	UT	ASC	HPP	AHPP
7	3.18 ± 0.10 <sup>a</sup>	0.77 ± 0.04 <sup>a</sup>	3.23 ± 0.10 <sup>a</sup>	0.53 ± 0.62 <sup>a</sup>
14	4.43 ± 0.11 <sup>b</sup>	1.23 ± 0.14 <sup>b</sup>	4.47 ± 0.11 <sup>b</sup>	1.15 ± 0.41 <sup>b</sup>
28	4.47 ± 0.03 <sup>b</sup>	1.82 ± 0.08 <sup>c</sup>	4.57 ± 0.03 <sup>b</sup>	1.31 ± 0.50 <sup>b</sup>

Values are expressed as means ± SD. The values with different superscript letters in a column are significantly different ( $p < 0.05$ ).

#### 4.4.5 Texture Profile

The textural properties of cream cheeses, such as firmness, spreadability and adhesiveness, were merely affected by the different treatments of avocado puree and storage time as shown in Figure 4.6. It should be mentioned that overall, the textural properties observed between or within the samples during storage had no consistent trend or pattern in differences or changes that could be attributable to the different treatments of avocado used in this study because of the data fluctuation to some extent in addition to a relatively very small difference in values.

In terms of firmness which represents the strength of the cream cheese matrix (Figure 4.6A), the firmness of cream cheese samples with HPP treated avocado puree, including HPP samples and AHPP samples, was slightly softer (0.89 N and 0.90 N, respectively) compared to the cream cheese sample (UT) containing untreated avocado puree (1.00 N) on the first day of storage. On the other hand, the cream cheese sample containing ascorbic acid-treated avocado puree showed a slightly higher firmness value during storage. Storage time had no pronounced effect on the firmness of cream cheese samples as there was no significant difference ( $p < 0.05$ ) in firmness between the values of beginning and the end of the storage, which indicated that treated avocado puree in this study did not affect the stability of firmness in cream cheeses during storage.



**Figure 4.6 Changes in textural properties, such as firmness (A), spreadability (B) and adhesiveness (C), of cream cheese samples with differently treated avocado puree (UT, ASC, HPP, AHPP) during storage for 4 weeks at 4°C.**

The samples with different superscript letters within each storage day are significantly different ( $p < 0.05$ ).

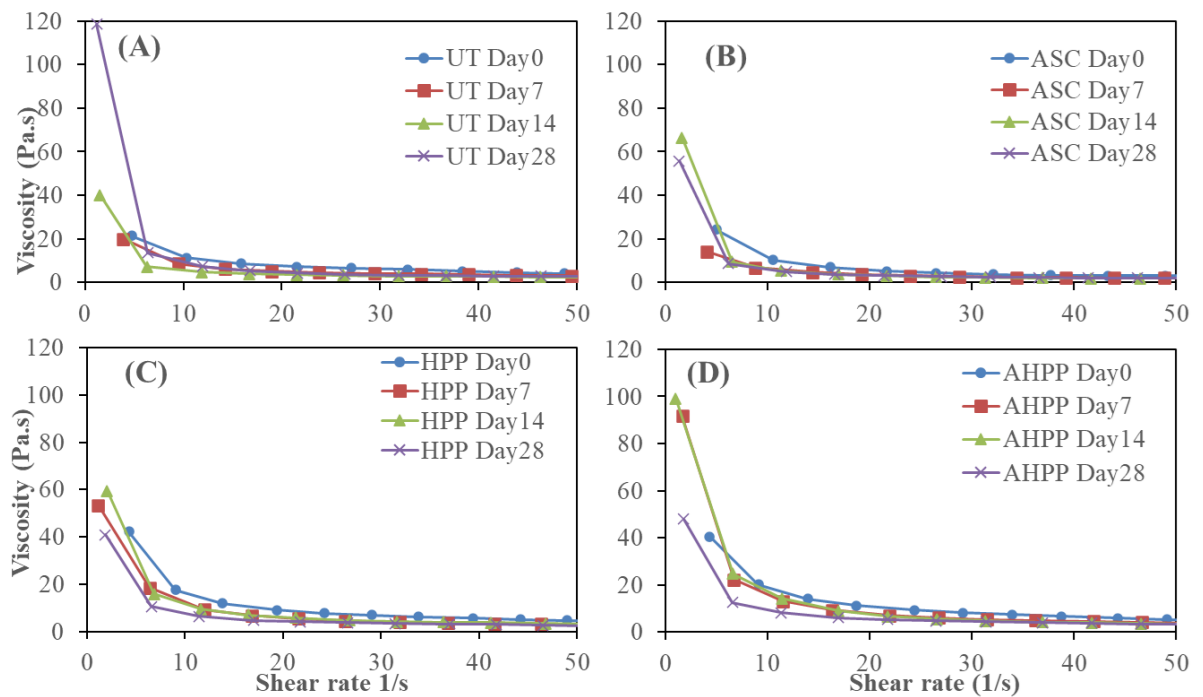
Spreadability is another attribute of textural properties used to describe how easily a food is spread over a flat surface. Figure 4.6B shows that at day 1, the HPP-treated samples (HPP and AHPP) were more spreadable than the UT and ASC samples. For example, the HPP sample's spreadability value was relatively lower (4.85 N/s) than the UT sample (5.77 N/s). However, after storage for 28 days, the HPP-treated samples, including HPP and AHPP samples, were less spreadable than the UT sample. On the other hand, the ASC sample showed an increased spreadability value than the UT sample, indicating that ascorbic acid could make an avocado fortified cream cheese harder to spread. As for the storage aspect, storage time could not significantly affect the spreadability in all avocado fortified cream cheese samples. Most of the samples' spreadability values were not significantly different ( $p < 0.05$ ) between day 1 and day 28, except HPP and AHPP samples. These two samples had a significantly higher spreadability values after 28 days storage compared to the beginning of storage, and the increased value of the HPP sample was much more than the AHPP sample, indicating that high pressure treatment of avocado puree may have less stability of spreadability inside the cream cheese.

The adhesiveness of textural properties is another parameter often determined in characterising the texture of cream cheese. The term 'adhesiveness' is defined as the negative force area for the first bite, representing the work needed to transfer food from the surface of other materials that come into contact (e.g. human tongue) (Bayarri et al., 2012; Bryant et al., 1995). The higher value of adhesiveness usually implies a soft texture (Chandra & Shamasundar, 2015). This study found that the UT sample had less adhesiveness than the other samples containing treated avocado puree (Figure 4.6C). There was a significant difference between the adhesiveness values of different samples in this study. All cream cheese samples containing HPP or ascorbic acid-treated avocado (ASC, HPP, and AHPP) had a higher adhesiveness value than UT samples, especially the HPP-treated samples (HPP and AHPP) after 28 days. The UT sample's adhesiveness value was -2.27 N/s at day 1, while the HPP and AHPP samples were -2.45 N/s and -2.94 N/s, respectively. According to Landl et al. (2010), HPP could increase the linearity of cell walls

and volumes of particles so that the viscosity of the puree could be increased, causing higher adhesiveness. After storage, the difference in adhesiveness between the samples with treated avocado became more pronounced. To be specific, adhesiveness values of ASC, HPP, and AHPP samples were -2.28 N/s, -3.01 N/s, -3.34 N/s, respectively, after storage for 28 days, but it was only -2.15 N/s for the UT sample.

#### **4.4.6 Flow Behaviour of Avocado-fortified Cream Cheese**

The rheological properties of cream cheese samples containing avocado puree were analysed. Figure 4.7 shows the flow curves of viscosity changes in samples during storage after 0, 7, 14 and 28 days. In all cases, the viscosity of cream cheese samples containing avocado puree with different treatments decreased when the shear rate increased, and then the viscosity had the tendency to equalise gradually. This is a characteristic of some non-Newtonian fluids which can be described as a shear-thinning behaviour, and the shear-thinning behaviour has been reported in some previous studies related to cream cheese (Brighenti et al., 2018; Fox et al., 2017; Lemes et al., 2016). Among the four different cream cheese samples, the control sample containing untreated avocado puree (UT) seemed to have a slightly higher viscosity than the other samples (ASC, HPP and AHPP). However, it was not significantly different ( $p < 0.05$ ). As for the effects of treatments during storage, all cream cheese samples containing avocado puree treated by various methods showed no significant difference in their viscosities during storage, shown in Table 4.4 as an example at 50/s shear rate ( $\eta_{50}$ ).



**Figure 4.7** Values of apparent viscosity as a function of shear rate for cream cheeses mixed with the avocado puree with different treatments (UT, ASC, HPP and AHPP). Measurement was conducted during storage (0, 7, 14 and 28 days) at 4°C.

**Table 4.4** The apparent viscosity (at 50/s shear rate) for cream cheese samples containing avocado puree treated by different methods (UT, ASC, HPP and AHPP), which were measured at different storage times (0, 7, 14 and 28 days) at 4°C.

Storage (day)	UT	ASC	HPP	AHPP
0	3.85 ± 0.48 <sup>Aa</sup>	3.08 ± 0.12 <sup>Aa</sup>	4.80 ± 0.32 <sup>Aa</sup>	4.59 ± 0.95 <sup>Aa</sup>
7	2.87 ± 0.36 <sup>ABab</sup>	2.13 ± 0.20 <sup>Bb</sup>	3.16 ± 0.41 <sup>ABab</sup>	3.66 ± 0.14 <sup>Aab</sup>
14	2.32 ± 0.01 <sup>Abab</sup>	1.76 ± 0.03 <sup>Ba</sup>	2.76 ± 0.48 <sup>Bbc</sup>	3.42 ± 0.04 <sup>Ac</sup>
28	2.26 ± 0.47 <sup>Ba</sup>	2.11 ± 0.31 <sup>Ba</sup>	1.92 ± 0.70 <sup>Ba</sup>	2.86 ± 0.44 <sup>Aa</sup>

<sup>A, B</sup> Within a column, different superscript capital letters denote significant differences ( $p < 0.05$ ) different types of cream cheese on the same days of storage.

<sup>a, b, c</sup> Within a row, different lowercase superscripts denote significant differences ( $p < 0.05$ ) between different days of storage for each type of cream cheese.

#### 4.4.7 Microstructure of Avocado-fortified Cream Cheese

The microstructures of four cream cheese samples containing 20% (w/w) avocado puree

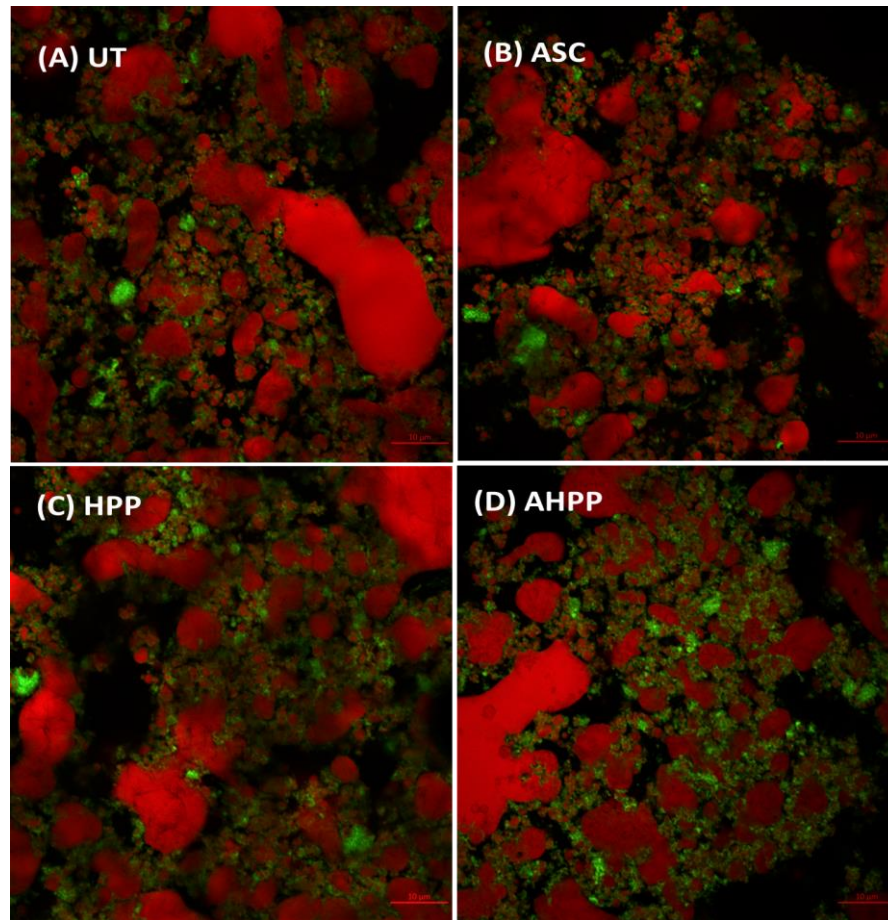
treated by different methods were visualised by confocal laser scanning microscopy (CLSM) (Figure 4.8). The protein network and aggregates were stained in green, and fat was stained in red in the images. The CLSM images show that the four cream cheese samples do not exhibit many differences in their microstructural features. This suggests that the different methods and conditions of treatments applied to avocado puree used in this study did not significantly affect the microstructures of the resulting avocado-fortified cream cheeses. As shown in Figure 4.8, all samples had protein aggregates with different sizes (smaller or larger) and clusters of protein aggregates surrounding fat droplets with different sizes, indicating that the cream cheeses prepared in this study by adding avocado puree were not highly homogenous. Also, some very large bulk oil (e.g. free oil, unemulsified oil) was observed in the CLSM images, which might have been mainly derived from avocado puree containing avocado oil. In this study, the mix of cream cheese and avocado puree (80:20) was not homogenised by a high-pressure homogenisation during the preparation of avocado cream cheese.

Nevertheless, the results of the microstructural analysis of cream cheese samples found in this study were in agreement with the previous study of Wendin et al. (2000), although there were some differences because of the different processing conditions and formulations used. They investigated the microstructures of cream cheeses produced at different levels of fat content (22, 28 and 34%) and salt content (1.4 and 0.7%) by using two different levels of high-pressure homogenization, i.e. 8000 kPa (80 bar) and 25000 kPa (250 bar). The CLSM images showed that the cream cheeses they prepared had both the fat and protein phases with the clusters of fat droplets with different sizes and uneven distribution, suggesting that the microstructure of cream cheese was affected by fat homogenisation pressure and salt content. It was also reported that the protein structures surrounding the fat droplets can be more or less dense and compact in cream cheese, depending on the chemical composition (e.g. protein, fat and salt contents). Also, according to Fenoul et al. (2008), the typical cream cheeses have a particulate microstructure comprised of aggregated protein clusters and pores. This study investigated the size measurement of aggregated protein particles from 3

different cream cheeses using quantitative image analysis of CLSM images. The formulations for making cream cheeses contained different levels of fat (6.9-13.1%) and protein (9-16.5%) which were processed by high pressure homogenization at 54000 kPa (540 bars). The size of protein clusters in the CLSM images was reported to be in a range of around 2 – 30  $\mu\text{m}$  in diameter. The study suggested that the size of clusters could be more determined by process conditions applied in making the cream cheese rather than the cream cheese composition.

Overall, the microstructure of cream cheeses shown in Figure 4.8 indicates that the fat globules in all cream cheese samples containing differently treated avocado puree were centrally located in the clusters of protein aggregates. Also, the protein tended to adsorb and aggregate at the surface of the cluster structure to form an interface between the aqueous and lipid phases. Some of these microstructural features were also reported by Kalab et al. (1981), who investigated the microstructure of commercial cream cheeses using cold-stage scanning electron microscopy (SEM). In addition, Figure 4.8 shows that several relatively very large irregular fat droplets (e.g. unemulsified free fat) tended to be dispersed among the clusters of aggregates in all cream cheese samples. Lenze et al. (2019) indicated that these fat droplets could be resulting from the de-emulsification of fat globules during the cream cheese manufacture caused by the coalescence of fat globules.

As for the unstained black area is another cream cheese's characteristic microstructural feature representing the serum phase in cream cheese (Fenoul et al., 2008). This serum phase area mainly depended on the moisture content level in cream cheese, and it tended to be more prominent in products having a high-water content (Macdougall et al., 2019). In this study, the black areas of all cream cheese samples containing treated avocado puree were similar because of the same formulation, in terms of its chemical composition, between all cream cheese samples.



**Figure 4.8 CLSM images of microstructures of cream cheeses containing 20% avocado puree treated by different methods (UT, ASC, HPP, and AHPP). Fat, protein and serum phases appear red, green and black, respectively.**

#### **4.5 Conclusions**

Four cream cheese samples with 20% of differently treated avocado puree were prepared and analysed during storage for 4 weeks. Some significant differences in parameters (e.g. syneresis, microbial stability, colour and texture) were observed among the samples, while some (e.g. viscosity and microstructure) were not different. This means that avocado puree treated by various methods could cause a series of effects on avocado-fortified cream cheese's quality, such as inhibiting browning and harmful microbes. Adding extra ascorbic acid in avocado puree seemed to decrease the colour change of avocado-fortified cream cheese by inhibiting browning, but ascorbic acid seemed to make the cream cheese sample harder, less spreadable, and less viscous. As for HPP treated samples, HPP-treated avocado puree could not significantly increase the colour stability of cream cheese during storage,

and HPP could make the sample have a better texture attribute. Besides, adding ascorbic acid in HPP-treated avocado puree could make the sample have minor colour changes and acceptable physicochemical properties. All treated avocado puree in cream cheese would have better microbiological safety than the control sample in microbiological tests. However, rheological studies demonstrated no significant difference in viscosity between the cream cheese samples

Therefore, considering keeping the typical characteristics of the cream cheese and the processing methods, one avocado puree treatment could be suggested to develop further avocado-fortified cream cheese, which adds ascorbic acid as an additive in HPP-treated avocado puree. Based on the above information, this kind of treated sample would have minor colour change and syneresis in cream cheese samples and have relatively small impacts on cream cheese's textural properties and flow behaviour. Moreover, the HPP treatment used in avocado puree may improve its mouthfeel, enhancing the sensory grades based on the outcomes from the sensory evaluation (Chapter 5). The results in this chapter indicate that adding ascorbic acid in HPP-treated avocado puree would have almost no significant effect on the quality and stability of cream cheese fortified with 20% avocado puree. A comprehensive sensory evaluation based on this formulation was conducted and discussed in Chapter 5.

## **Chapter 5. Sensory Evaluation of Avocado-fortified Cream Cheese: Effects of Avocado Puree Concentrations and Processing Conditions**

### **5.1 Abstract**

The addition of avocado puree in cream cheese could increase its nutritive value and sensory quality. A sensory evaluation with two sensory tests was conducted to evaluate consumer acceptability of avocado-fortified cream cheese about the optimum level and treatments of avocado puree. The first sensory test aimed to evaluate the four cream cheese samples with different concentrations of avocado puree (0, 10, 20 and 30%AVP) to identify consumer preferences for the level of avocado puree concentration. The 20%AVP was found the most acceptable avocado puree concentration to be mixed with cream cheese. In the second sensory study, three treatments were chosen to apply on fresh avocado puree to slow down its degradation and enzymatic browning, including high-pressure processing (HPP), ascorbic acid (ASC), and HPP plus ascorbic acid (AHPP). This sensory test was conducted to evaluate the sensory characteristics of cream cheese after mixing with 20% avocado puree that was untreated (UT) or treated by the different methods (HPP, ASC, AHPP). Results showed that sensory characteristics of cream cheese containing HPP-treated avocado puree did not differ significantly from the cream cheese with untreated avocado (control sample) (UT). However, cream cheese with ascorbic acid-treated avocado puree (ASC) seemed to have significantly higher sourness than the control sample, and this sample gained the least score from hedonic evaluation in this study. Besides, the cream cheese (AHPP) with the treatment of ascorbic acid and HPP avocado puree had better sensory attributes than the other samples, including texture and taste characteristics. Thus, in this study, an optimum incorporation rate for the avocado puree to mix with cream cheese was found to be 20%. The combination of HPP and the ascorbic acid-treated avocado puree was identified to be a suitable method in the protection and improvement of avocado-fortified cream cheese's sensory attributes.

## 5.2 Introduction

Cream cheese is an unripened, acid-coagulated, and creamy cheese product with a relatively high level of moisture and fat content (Kosikowski & Mistry, 1997). Due to its relatively high-fat content, some studies have been conducted to improve the nutritional value of cream cheese to meet the requirements of health-conscious consumers by mixing cream cheese with other ingredients (e.g. fruit concentrate, vegetable organogels, buttermilk) (Bahrami et al., 2015; Bemer et al., 2016; Limanowski, 2016).

Avocado is a fruit that is comprised of greenish or yellowish flesh, a large seed and dark leathery skin. It is scientifically known as *Persea americana* (Ashton, 2005; Dreher & Davenport, 2013; Schaffer et al., 2013). Avocado is well known for its high nutritional value to provide a range of health benefits. It provides a high amount of monounsaturated fatty acids and fibre. It is rich in various other nutrients, such as minerals (e.g. magnesium and potassium), vitamins (e.g. A, D, E and B6), carotenoids (e.g. beta-carotene and lutein), omega-3 fatty acids, etc. (Ashton, 2005; Dreher & Davenport, 2013; Mahmassani et al., 2018; Marcos et al., 2019). In addition, the content of protein in avocado is much higher than other fruits (Ashton, 2005). Therefore, avocados have become a prevalent food in the past decades. In terms of its sensory properties, a ripe fresh avocado has a soft, smooth and creamy texture and has a mild flavour and taste, making them highly suitable for some food formulations as a functional ingredient for numerous benefits. Therefore, adding avocado (e.g. avocado puree or paste) into cream cheese can be considered an opportunity to develop a new type of cream cheese with health benefits that can be introduced into the market as a value-added functional product.

Avocado is a highly perishable fruit with an extremely short shelf-life compared to other fruits because of its high metabolic rate (Yahia & Gonzalez-Aguilar, 1998). Especially, fresh-cut avocado fruits are not stable and undergo considerable deterioration, in terms of their sensory characteristics, nutritional value, microbial safety, and aesthetic appeal, through a series of physical and chemical reactions and biological activity (Bustos et al.,

2017; Singh et al., 2018; Soliva et al., 2000; Son et al., 2001. Besides, the shelf-life of avocado puree (about two days at room temperature optimistically) is shorter than the entire fruit due to the release and exposure of chemical components (e.g. lipid, polyphenols, enzymes, etc.) from the plant tissues to oxygen in the air, thus promoting the oxidation processes in both lipid and aqueous fractions (Balda et al., 2011). Enzymatic browning is one of the oxidation reactions taking place in avocado, which is a crucial factor to negatively affect the sensory qualities of avocado (Robards et al., 1999).

Studies have shown that ascorbic acid is a powerful antioxidant that can be used to preserve colour degradation and prevent or delay the browning reaction of avocado (Bustos et al., 2017; Singh et al., 2018; Soliva et al., 2000). High-pressure processing (HPP) is another method that can be used to reduce the browning of avocado by reducing the activity of polyphenol oxidase (PPO) (Jacobo-Velázquez & Hernández-Brenes, 2010; Ludikhuyze et al., 2002; Malo et al., 1998; Torres & Velazquez, 2005). The use of ascorbic acid and/or HPP was investigated in Chapter 5. The results showed that a combination of ascorbic acid and HPP was suitable for preventing the browning without significantly affecting the quality of cream cheese fortified with treated avocado puree.

Developing a food product based on consumers' voices from the sensory evaluation can be vital for successful innovative food development (Song et al., 2018). A well-engaged sensory evaluation could find correlations between sensory properties and consumer preference, offering food developers a complete understanding of the product's performance and optimisation (Ng et al., 2013). Also, consumers' acceptance and preference of the product gathered from the sensory evaluation can indicate their prospective future purchase intentions (Kirkmeyer & Mattes, 2000; Ng et al., 2013). Although consumer's acceptance and preference are crucial in a sensory test, some other food basic parameters can also be evaluated to help producers fully understand their products from a sensory evaluation. For instance, some essential texture parameters of foods, such as firmness, spreadability, and adhesiveness, can be detailed described by a

sensory evaluation (Cardello, 1994; Gutjar et al., 2015; Köster & Mojet, 2015).

However, there was limited research published about developing an avocado-fortified cream cheese and relevant consumer's opinions. Also, related avocado-fortified cream cheese products were still lacking in the market. This study aims to elaborate and evaluate the sensory characteristics of cream cheese with different concentrations (0%, 10%, 20%, and 30%) of avocado puree and cream cheese containing differently treated avocado puree at a particular concentration (20%). This study can provide some essential properties of this new food product and detect the suitable concentration and treatment of avocado puree for cream cheese to conduct further studies.

### **5.3 Materials and Methods**

#### **5.3.1 Materials**

In this study, all the materials and ingredients (e.g., milk, avocados, starter culture, rennet, etc.) applied in manufacturing cream cheese fortified with avocado puree were the same as described in Section 3.3.1 and Section 4.3.1.

#### **5.3.2 Sample Preparation**

Figure 3.1 in Chapter 3 of this thesis shows the diagram for manufacturing cream cheese in this study based on the methods of Ningtyas et al. (2018) and Phadungath (2005). A temperature-controlled water bath (T100, Grant Instruments, UK) was used for cream cheese fermentation and resetting. The cheese curd was mixed with several ingredients (0.1% garlic powder, 0.5% salt, and 0.3% locust bean gum) by a hand blender (Living & Co 250W Stick Mixer, New Zealand) after expelling out the whey.

Ripe avocados were washed, cored, and cut into halves lengthwise using a knife. Individual avocado half was vacuum packaged into a plastic bag (Contour International Limited, New Zealand) impermeable to oxygen by a packaging machine (Type-C300, MULTIVAC, Germany). Then, the avocado halves were stored at -20°C until used. For the treatment of

avocados by HPP, some avocado halves were thawed at 4°C overnight and then high pressure processed at 600 MPa for 10 min at 20°C using a 55 L HHP unit (Uhde High-Pressure Technologies, Germany), as shown in Figure 4.1 of Chapter 4. The HPP-treated avocado halves were stored at -20°C until use for further experiments.

Before making avocado puree, the frozen avocado halves, including HPP-treated avocado halves and untreated avocado halves, were placed in a fridge at 4°C for one day in advance for thawing. Then, the avocado halves were grounded in a sanitised stainless bowl and homogenised into puree by a hand mixer (Living & Co 250W Stick Mixer, New Zealand). The avocado purees prepared were then mixed with the freshly prepared cream cheese to make avocado-fortified cream cheeses as described in Section 3.3.3 in Chapter 3.

### **5.3.3 Samples codes of cream cheese samples**

There were two sensory tests conducted in this study. The first sensory test samples were cream cheeses mixed with four different concentrations (0%AVP, 10%AVP, 20%AVP, and 30%AVP) of avocado puree (Table 5.1). These samples were prepared one day in advance and refrigerated at 4 °C until the moment of serving. The preparation of samples is described in Section 3.3.3 in Chapter 3. The results of the first sensory test were used as the guide for the next sensory test. As for the second sensory test samples, cream cheese samples were mixed with a 20% (w/w) concentration of avocado puree treated by different treatments according to Section 4.3.4 in Chapter 4. These sample codes are shown in Table 5.1 along with the other 4 samples as described above.

**Table 5.1 Sample codes of cream cheese samples which were analysed by the sensory evaluation.**

	Sample code	Avocado %	Avocado Treatment	Cream cheese %	Salt %	LBG %	Garlic powder %
1 <sup>st</sup> sensory test	0%AVP	0	No treatment	100	0.5	0.3	0.1
	10%AVP	10	No treatment	90	0.5	0.3	0.1
	20%AVP	20	No treatment	80	0.5	0.3	0.1
	30%AVP	30	No treatment	70	0.5	0.3	0.1
2 <sup>nd</sup> sensory test	UT	20	No treatment	80	0.5	0.3	0.1
	ASC	20	2% ASC	80	0.5	0.3	0.1
	HPP	20	HPP	80	0.5	0.3	0.1
	AHPP	20	2 % ASC and HPP	80	0.5	0.3	0.1

AVP: avocado puree, LBG: locust bean gum, UT: untreated, ASC: ascorbic acid, HPP: high-pressure processing, and AHPP: ascorbic acid/high-pressure processing.

### 5.3.4 Sensory Evaluation

#### Participants

A total of 37 participants participated in the first sensory test. Another group of 31 participants conducted the second sensory test. Inclusion criteria were age between 18 and 60 years, being a consumer of cream cheese products (defined as eating cream cheese at least once per year in this study). Exclusion criteria were pregnancy, lactation, allergy or sensitivity to cream cheese ingredients, such as milk protein, avocados, garlic powder and other ingredients. Participants were aware of the study's approximate aim, and all participants signed informed consent. The Massey University Human Ethics Committee approved both sensory tests: Southern A, Application 4000023103.

#### Procedure

The first sensory test was performed in a cafeteria in Albany, Auckland, New Zealand (HTC Net Cafe, Albany), where the participants' responses to the four cream cheese samples containing different concentrations of avocado puree (0%AVP, 10%AVP, 20%AVP, and

30%AVP) were measured. Before the test, participants were given instructions to inform them about its comprehensive information, such as sample ingredients and project goals. Each sample was presented in a 20 ml disposable transparent sample cup containing about 10 g of sample and a disposable small transparent teaspoon. Samples were presented simultaneously, and participants were instructed to taste samples with the spoon after observation. Participants could taste the sample more than once while ranking the preference. After evaluating all samples, participants were asked to rank how much they liked the sample following the order from the most favourite sample to the least favourite one (the most liked sample got a score of 4, the least liked one got a score of 1). Participants were asked to eat an unsalted cracker and rinse their mouths with water between samples. The purpose of the first sensory evaluation was to see an optimal level of avocado concentration that needs to be incorporated into cream cheese.

The second sensory test procedure was similar to the first sensory test but the second sensory evaluation was performed in the Food Technology Sensory Laboratory, Massey University, Auckland. The samples used in the second sensory test were the four cream cheese samples containing 20% of avocado puree with different treatments (UT, ASC, HPP, and AHPP). The 20% avocado was chosen based on the results of the first sensory evaluation. The second sensory test focused on evaluating samples' sensory attributes and which sample they preferred (blind choice context). Samples were presented to the participants in a 20 ml disposable transparent sample cup containing a standard serving of about 10 g of sample and a disposable teaspoon for one person per sample. Participants received the samples and tasted the samples in random order. After each sample tasting, participants were asked some descriptive questions about the sample's vital sensory attributes with scale ranging from 0 to 5 and their preference of each sample through a 9-point hedonic scale (1 = "dislike extremely", 9 = "like extremely"). All participants were asked to use water and an unsalted cracker to clean their mouths between samples.

According to several previous studies (Apilado et al., 2013; Bahrami et al., 2015; Song et

al., 2018; Wendin et al., 2000), there are six quality attributes usually assessed in the sensory evaluation of cream cheese, including spreadability, firmness, sourness, stickiness, smoothness and creaminess. Therefore, this sensory test also assessed these sensory attributes defined in Table 5.2, including some other attributes (e.g. flavour, colour, flavour, aftertaste). The numerical intensity scale for each attribute ranged from 0 to 5, and a higher number indicated a greater intensity. The list of questions (sensory questionnaires) used in the first and second sensory tests can be found in Appendix 2 and Appendix 3, respectively.

**Table 5.2 Sensory attributes and definitions used to describe cream cheese.**

<b>Attribute</b>	<b>Definition</b>
<b>Spreadability</b>	The force needed to spread the sample
<b>Sourness</b>	The taste from acids, such as lactic acid
<b>Firmness</b>	Resistance against the palate during mastication
<b>Smoothness</b>	The level of particles or lumps in the sample
<b>Creaminess</b>	The flavour associated with whipped cream
<b>Stickiness</b>	Stickiness between the tongue and upper palate

### **5.3.5 Data Analysis**

Participants were asked to fill up the information and questions using an iPad provided to them, and the sensory data were collected by the RedJade sensory software (Tragon Corporation, USA) to assess the consumer sensory evaluation. The results of the sensory evaluation were statistically analysed using the Minitab Statistical Software (Minitab 19 Statistical Software, USA) for one-way analysis of variance (ANOVA) at a significance level of  $p < 0.05$ , and SPSS statistics version 23 software (IBM, Armonk, USA) was used for principal component analysis (PCA).

## **5.4 Results and Discussions**

### **5.4.1 Ranking for Preference of Avocado Puree Concentration**

Many studies have applied various sensory evaluation methods to know participants'

preference for samples, including the hedonic ranking test, which was initially used by Tepper et al. (1994). It is a preference test with a self-adjusting scale, and it has been regarded to have the lowest discriminability (Villanueva et al., 2000). In the first sensory test session, four cream cheese samples containing different levels of avocado puree (0, 10, 20 and 30%) were manufactured as the test material to investigate participants' (n=37) preference for avocado puree concentrations in cream cheese to select a proper avocado puree concentration mixing with cream cheese for further investigations.

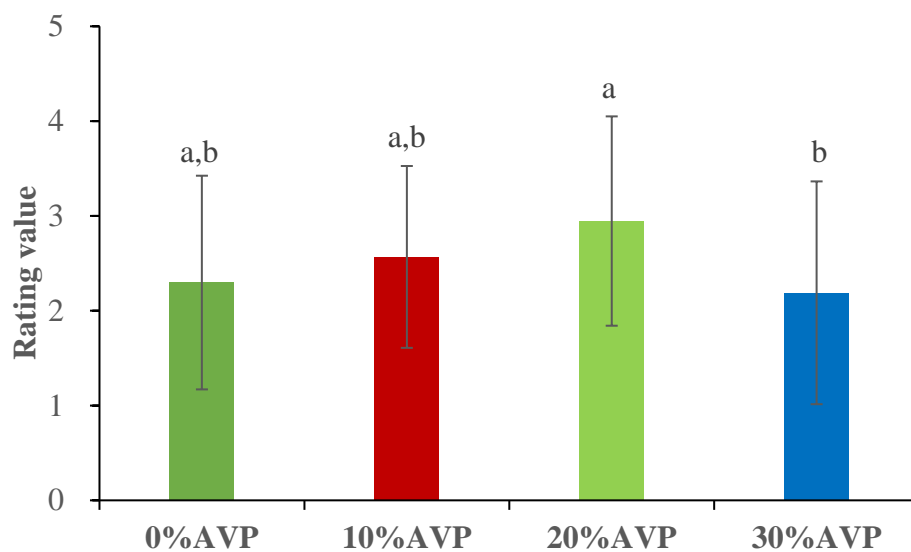
Table 5.3 presents the ranking results of cream cheese samples containing four concentrations of avocado puree (0, 10, 20 and 30%) to evaluate participants' overall preferences. Most participants favoured the sample 20%AVP, and 70.27% of participants ranked the sample 20%AVP first and second. More than half of the participants ranked 0%AVP (56.75%) and 30%AVP (64.87%) in the last two places. These results indicate that the participants mostly prefer the cream cheese sample with a 20% concentration of avocado puree, and that they liked the sample 30%AVP but 0%AVP least.

**Table 5.3 Results of participants ranking cream cheese samples. Percentage means the percentage of participants (n=37) in this sensory test.**

<b>Rank</b>	<b>0%AVP</b>	<b>10%AVP</b>	<b>20%AVP</b>	<b>30%AVP</b>
<b>Rank 1</b>	18.9%	18.9%	40.5%	21.6%
<b>Rank 2</b>	24.3%	32.4%	29.7%	13.5%
<b>Rank 3</b>	24.3%	35.1%	13.5%	27.0%
<b>Rank 4</b>	32.4%	13.5%	16.2%	37.8%

The average rating values of these four cream cheese samples in terms of overall preferences of samples evaluated by the ranking method (n=37) is shown in Figure 5.1. As mentioned in Section 5.3.4, for easier visual inspection, the participant's most liked sample would get the score of 4, and the least liked sample get the score of 1. The mean rating values shown in Figure 5.1 were in line with the findings of the ranking results (Table 5.3). Figure 5.1 shows that 20%AVP was still the most popular sample among all samples, but

20%AVP's score was only slightly higher and not significantly different from the samples 0%AVP and 10% AVP ( $p < 0.05$ ). In contrast, a significant difference in rating values was found between 20%AVP and 30%AVP out of four samples. Importantly, although there were no significant differences among the three samples' rating values (0%AVP, 10%AVP and 20%AVP), both Table 5.3 and Figure 5.1 point out the same outcomes, which were that sample 20%AVP was liked most by participants, and sample 30%AVP had the lowest degree of preference.



**Figure 5.1 The average rating values of four cream cheese samples were assessed by participants.**

The values with different superscript letters differ significantly ( $p < 0.05$ ).

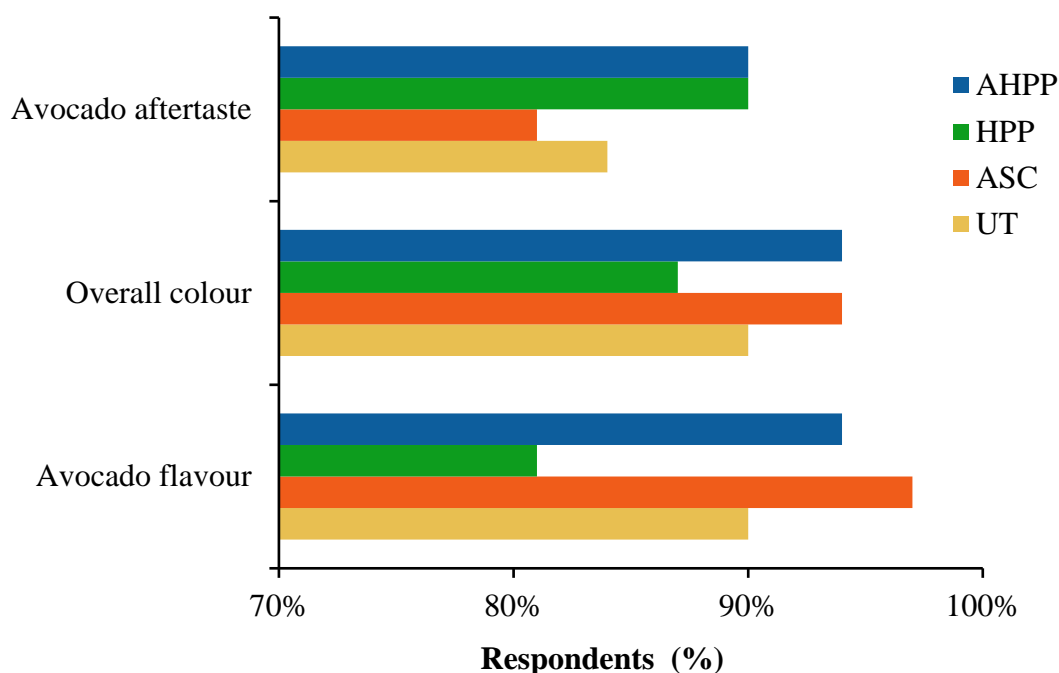
The decision about the overall preferences of samples is based on the participants' ranking after tasting the product (Andersen et al., 2019). In this study, sample 20%AVP was the most popular product based on the results, presenting cream cheese fortified with 20% avocado puree could be the most acceptable sample. However, the avocado puree was treated as indicated in Table 5.1 by different methods (UT, ASC, HPP and AHPP) prior to its mixing with cream cheese. Since more participants prefer the sample 20%AVP, a follow-up study was also carried in section 5.4.2 to research the effects of 20% avocado puree on the cream cheese's sensory attributes after mixing, including spreadability, firmness, sourness, stickiness, smoothness, and creaminess.

#### **5.4.2 Sensory Characteristics of Cream Cheese with 20% Avocado Puree Treated by Different Methods**

In the second sensory research, the just-about-right (JAR) scale and the hedonic scale were applied to assess participants' preference level and reconfirm whether cream cheese's avocado puree level is suitable. The JAR method is a typical method to ask participants whether the sample's characteristics are just right or not to directly collect and analyse feedback (Popper, 2005; Rothman, 2007). The hedonic scale method would use a balanced bipolar scale having categories labelled with phrases presenting participants' liking degrees centred around the neutral description (Lim & Fujimaru, 2010; Villanueva & Da Silva, 2009). Usually, the JAR and hedonic scales can be combined to apply in a single sensory test to provide much detailed information of products (Zhi et al., 2016).

##### **JAR for Avocado-Related Sensory Attributes**

The JAR evaluation of three attributes related to avocado puree by participants (n=31) is shown in Figure 5.2. Respondents from three aspects (avocado aftertaste, overall colour, and avocado flavour) rated the just-about-right level of cream cheese samples (UT, ASC, HPP, and AHPP) related to sensory properties of avocado puree. The results showed that the respondents from participants rated sample UT having the just-about-right level for avocado aftertaste (84%), overall colour (90%), and avocado flavour (90%); sample ASC having the just-about-right level for avocado aftertaste (80.6%), overall colour (93%), and avocado flavour (97%); sample HPP having the just-about-right level for avocado aftertaste (90%), overall colour (87%), and avocado flavour (81%); and sample AHPP having the just-about-right level for avocado aftertaste (90%), overall colour (93%), and avocado flavour (93%).



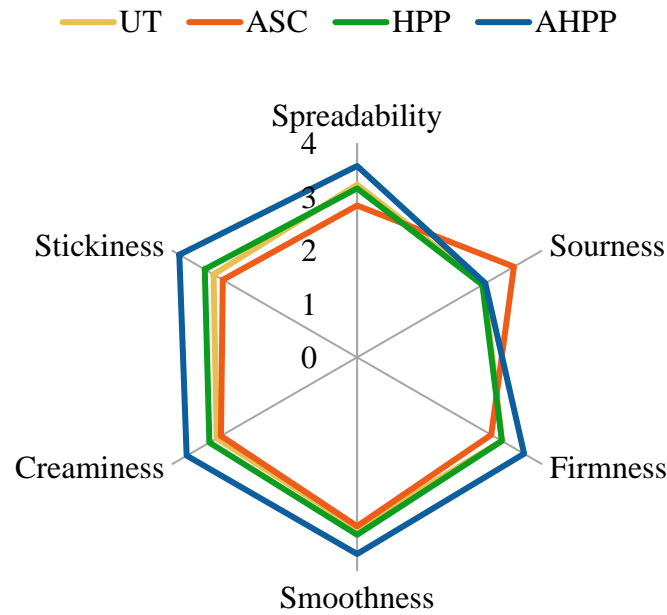
**Figure 5.2 Percentage of respondents for the just-about-right (“JAR”) level of the aftertaste, overall colour, and avocado flavour of cream cheeses containing 20% avocado puree treated by different methods (UT, ASC, HPP and AHPP).**

According to Xiong and Meullenet (2004), if 70% of responses are at the just-about-right level from the sensory test, it can conclude that the particular attribute is at an optimal level. Therefore, all samples in this study could be optimal for the avocado aftertaste, overall colour, and avocado flavour. Besides, from the results of these avocado-related attributes, samples ASC and AHPP showed a more significant number of respondents for just-about-right level for overall colour attributes. Participants thought the colour of these two samples being at the just-about-right level. This finding is in line with Chapter 4, in which ASC and AHPP samples had better colour preservation effects on avocado puree. However, for the sample ASC, most participants thought the avocado flavour of this sample was at the just-about-right level than other samples. Also, the avocado flavour part results are consistent with the first sensory analysis in Chapter 5.4.1, which indicated that participants could accept 20% of added avocado puree in cream cheese most among all avocado puree concentrations.

### **Sensory Evaluation for Cream Cheese Sensory Attributes**

Cream cheese samples may gain some unique sensory qualities from treated avocado puree. Thus, a spider plot has been conducted to visualise the differences in sensory profiles among cream cheese samples (He et al., 2009). The attribute intensities for four samples with six common sensory characteristics (spreadability, firmness, sourness, stickiness, smoothness and creaminess) used to describe cream cheese are described in a spider plot in Figure 5.3.

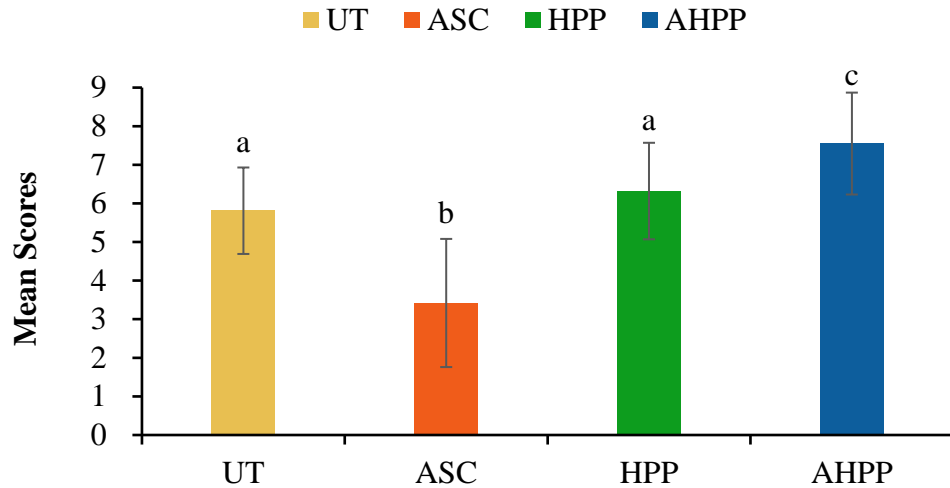
One of the samples (ASC) showed a much stronger sour flavour than other samples (Figure 5.3), which could be contributed by the added ascorbic acid and a slightly lower spreadability, firmness, stickiness, smoothness, and creaminess. As for the AHPP sample, the values of all sensory attributes were significantly higher than other samples, except sourness (Figure 5.3). The higher values of this sample's sensory attributes evidenced the improvement of cream cheese's sensory profile by combining HPP and ascorbic acid's effects. Besides, the HPP sample's sensory profile appears to be more balanced in Figure 5.3, but this sample had lower sensory attributes values than ASC and AHPP. The values of the HPP sample's sensory attributes were quite similar to the UT sample, especially in spreadability, firmness, and sourness. Overall, it is necessary to highlight that the AHPP sample tended to have better textural characteristics and taste features than other samples in this study, including the cream cheese sample containing untreated avocado puree.



**Figure 5.3 Spider plot for essential sensory attribute scores of cream cheese samples containing avocado puree treated by different methods (UT, ASC, HPP and AHPP).**

### Consumer Preference Results

Figure 5.4 shows participants' average preference evaluation results by the 9-point hedonic scale of four cream cheeses (UT, ASC, HPP and AHPP) (n = 31). The AHPP sample still had a higher average overall liking score than the other samples from this chart. From the perspective of avocado puree treatments, sample ASC was less liked by participants than the other samples. Based on the described sensory attributes shown in Figure 5.3, much sourness could be one of the principal reasons that affected participants' preference degree. As for samples UT and HPP, the hedonic scaling of these two samples resulted in insignificant hedonic discrimination between samples, indicating that HPP treatment would not affect the product's taste and participant's preference. In contrast to the hedonic evaluation of cream cheese samples, all treatments related to HPP on avocado puree (HPP and AHPP) in this study seemed to slightly improve cream cheese's overall preference degree.

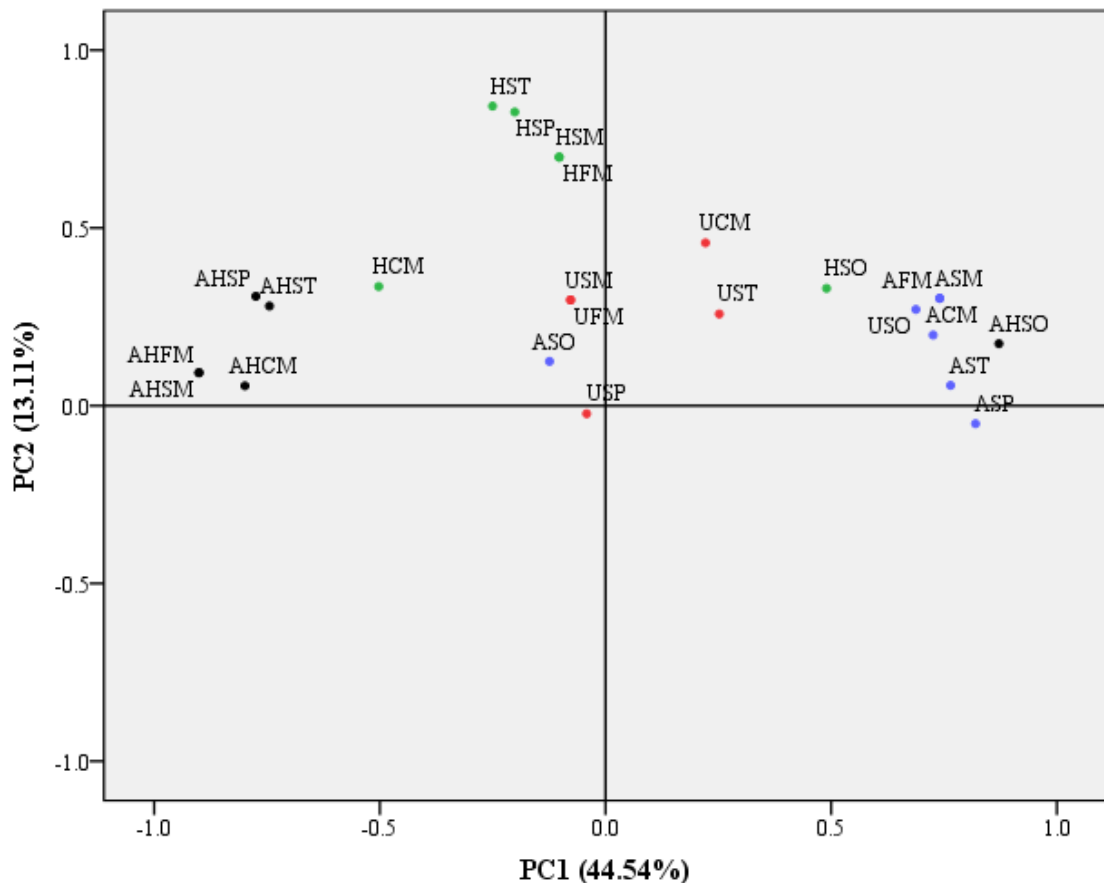


**Figure 5.4 Hedonic evaluation for cream cheese samples containing differently treated avocado puree (UT, ASC, HPP and AHPP) (n=31).**

A 9-point hedonic scale was used for preference (1 = dislike extremely, 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much, 9 = like extremely).

#### **Relationships among avocado puree's different treatments and sensory attributes**

A principal component analysis (PCA) was performed to visualise the relationships between cream cheese samples and selected significant sensory attributes (Figure 5.5). The component 1 (PC1) accounted for 44.54% of the observed variation, and the component 2 (PC2) accounted for 13.11% of the total variance (57.65% in total). PC 1 separated the cream cheese samples negatively related to the samples' firmness, creaminess, stickiness, smoothness, and sourness. PC 2 was also negatively linked with the sensory attributes of spreadability.



**Figure 5.5 Principal component analysis (PCA) biplot of sensory attributes of cream cheese samples.**

\* Letter symbols in the biplot graph indicate: PC1 = first principal component; PC2 = second principal component. USP = UT sample's spreadability; UST = UT sample's stickiness; UCM = UT sample's creaminess; USM = UT sample's smoothness; UFM = UT sample's firmness; USO = UT samples' sourness; ASP = ASC sample's spreadability; AST = ASC sample's stickiness; ACM = ASC sample's creaminess; ASM = ASC sample's smoothness; AFM = ASC sample's firmness; ASO = ASC samples' sourness; HSP = HPP sample's spreadability; HST = HPP sample's stickiness; HCM = HPP sample's creaminess; HSM = HPP sample's smoothness; HFM = HPP sample's firmness; HSO = HPP samples' sourness; AHSP = AHPP sample's spreadability; AHST = AHPP sample's stickiness; AHCM = AHPP sample's creaminess; AHSM = AHPP sample's smoothness; AHFM = AHPP sample's firmness; AHSO = AHPP samples' sourness; codes for samples correspond to codes in Table 5.1.

The sample groups spanned the sensory space quite well, as presented in the PCA biplot (Figure 5.5). Samples with different avocado puree treatments (ascorbic acid, HPP, and HPP combined with ascorbic acid) tended to be closely linked to each other based on their

particular treatments, which indicated that participants could taste the differences of treatments in samples. The UT sample's sensory attributes (spreadability, stickiness, creaminess, smoothness, firmness, and sourness) were mainly located near the biplot's origin so that the UT sample could be regarded as the control sample.

To compare the effects of different avocado puree treatments on avocado-fortified cream cheeses' textural characteristics, it was found that the HPP sample's texture attributes (HSP, HSM, and HFM) were located much closer to the control sample (Figure 5.5), indicating avocado puree would be changed slightly less in texture profiles after treated by HPP treatment, which was also in line with previous research by Tabilo et al. (2005) and the findings in Figure 5.3. Besides, AHSM and AHFM of the AHPP sample were located negatively further than the HPP sample in this biplot, which means that the AHPP sample showed better texture attributes than UT samples. Thus, the combination of ascorbic acid and HPP could be the reason to affect cream cheese's spreadability, smoothness, and firmness.

In terms of avocado puree treatment influences on cream cheese's taste, this study found that the ASC sample's creaminess and sourness (ACM and ASO) were located much further to the control sample than other samples. This indicated that the avocado-fortified cream cheese would have less creaminess and become sourer after adding ascorbic acid into the avocado puree. The addition of ascorbic acid may enhance the sour taste in samples ASC and AHPP to have a sourer taste intensity further than that of the control sample (Song et al., 2018). As for other samples, compared to AHPP, the HPP sample's creaminess and sourness were located relatively close to the control sample (UT), which demonstrated that HPP-related treatments could not significantly change the taste properties of avocado-fortified cream cheese at a 20% avocado puree concentration.

In summary, avocado-fortified cream cheese's texture and taste properties would have some negative changes caused by the added ascorbic acid in avocado puree, especially in

decreasing the creaminess and increasing the product's sour taste. The HPP treatment was found to have a minor effect on the product's sensory attributes, and the AHPP sample appeared to have better texture characteristics than other samples, including the UT sample. This indicated that HPP treatment could somewhat reduce the impact of added ascorbic acid on the product's texture.

## **6.5 Conclusions**

This project undertook two sensory tests to describe the sensory characteristics of avocado-fortified cream cheese. The first sensory test aimed to rank four cream cheese samples containing different avocado puree concentrations (0, 10, 20 and 30%) to represent a reasonable avocado puree concentration mixing with cream cheese. Based on the ranking test results, the cream cheese containing 20% of treated avocado puree was chosen to be applied in the second sensory test to evaluate the effect of avocado puree's different treatments on the cream cheese's sensory characteristics. Participants in this study thought that the sensory attributes of HPP-treated (HPP and AHPP) were similar to the control sample (cream cheese with untreated avocado puree). On the other hand, cream cheese with ascorbic acid-treated avocado puree had more sourness and less creaminess in taste, and this sample was also found to have fewer texture attribute scores than the control group. If both ascorbic acid and HPP treatment were applied on avocado puree, the taste and texture profiles of this sample would be slightly better than the other samples, indicating the effect of HPP treatment on reducing the negative impact of ascorbic acid, and this sample was the most acceptable sample according to the hedonic evaluation. This study indicated that the sensory acceptability of avocado-fortified cream cheese seemed to be different due to the various avocado puree concentrations and treatments, indicating that this comprehensive sensory evaluation is necessary to conduct in product development and optimisation.

## Chapter 6. Overall Conclusions & Recommendations

### 6.1 Research Outcomes

This research project was carried out to develop a new cream cheese formulated with avocado puree by investigating their vital physicochemical properties, microbial properties and sensory attributes. Different avocado puree concentrations and treatments were applied to determine the most appropriate avocado puree concentration and its treatment condition against enzymatic browning to ensure the avocado-fortified cream cheese having acceptable quality and stability for consumers. This research provides essential information for developing a commercial new cream cheese product containing avocado puree to fill some existing gaps in the market. Four concentrations of avocado puree (0%, 10%, 20%, and 30%) were added to cream cheese to study their effects on its formation and properties in this project. Besides, four avocado puree treatment conditions were also studied in this research, including no treatment (UT), ascorbic acid (ASC), high-pressure processing (HPP), and a combination of ascorbic acid and HPP (AHPP). According to a series of experiments in this project, avocado puree's concentrations and treatments were found to have a varying degree of effects on the colour, rheological and textural properties, microbiological safety, microstructure, sensory attributes, and stability of cream cheese, depending on the level of avocado puree concentration used and the type of treatment condition applied.

Different concentrations of avocado puree in cream cheese significantly changed the quality and stability parameters of cream cheese. Avocado puree-added cream cheese had more moisture, fat and ash contents so that a series of cream cheese's quality-related parameters were affected, such as higher syneresis and lower viscosity. Based on the results of this research, adding 10% and 20% avocado puree in cream cheese tended to have more stable texture quality and stability than cream cheese containing 30% avocado puree during storage. Avocado added cream cheese had the same shear-thinning flow behaviour as the

regular cream cheese, but avocado puree made cream cheese less viscous. Besides, cream cheese's colour was significantly changed by avocado puree, and more avocado puree contributed to more colour change and less colour stability during storage. In general, cream cheese with 30% avocado content negatively affected the quality and stability of cream cheese. Although adding 10% and 20% avocado puree had a relatively stable quality, the sensory evaluation pointed out that cream cheese with 20% avocado puree was more acceptable. On the other hand, considering the health benefits from avocado puree, cream cheese with more avocado concentrations should be selected. Thus, it is better to fortify cream cheese with 20% of avocado puree.

To keep cream cheese containing 20% avocado puree fresh during storage, several treatments were applied on avocado puree, as mentioned, and these treatments showed significant effects on the product stability parameters. Avocado puree's treatments had a series of beneficial effects to prove the quality of the product during storage, including inhibiting browning reactions and microbe's growth. Based on the results of this project, adding ascorbic acid in avocado puree provided cream cheese with a more stable colour by reducing browning reactions. However, ascorbic acid negatively affected the avocado-fortified cream cheese texture and rheology attributes, making the sample harder, less spreadable and less viscous. As for the HPP treatment, this study showed that cream cheese with HPP-treated avocado puree did not have significantly better colour stability than the control sample. Cream cheese containing treated avocado puree significantly enhanced microbiological safety than the cream cheese with untreated avocado puree. Notably, the addition of ascorbic acid in HPP-treated avocado puree had a minor effect on the quality and stability of cream cheese containing 20% of avocado puree. This treatment significantly improved the preservation of cream cheese's essential characteristics from avocado puree's degradation.

For the sensory evaluation, two interconnected sensory tests were conducted to describe avocado-fortified cream cheese's sensory characteristics in this project. The first test ranked

avocado-fortified cream cheese samples by different avocado puree concentrations, and the results showed that cream cheese containing 20% avocado puree was the most considerable avocado puree level. Thus, in the second sensory test, the effects of cream cheese with 20% differently treated avocado puree on its sensory characteristics were investigated. According to the results, participants thought that the cream cheese with HPP-treated avocado puree had close sensory attributes to the control sample (cream cheese containing 20% untreated avocado puree). However, the sensory evaluation found that ascorbic acid could make avocado-fortified cream cheese have more sourness and less creaminess, and this sample's texture attributes were not as acceptable as other samples. Impressively, if both ascorbic acid and HPP treatment were applied on avocado puree, the sensory profiles of the product were observed to be slightly better than the other samples, and this sample seemed to be the most acceptable sample by participants. In conclusion, among all the different trials investigated in this study, the cream cheese formulation with 20% avocado puree treated with a combination of HPP and ascorbic acid was most suitable for preserving and improving the sensory attributes of cream cheese fortified with avocado puree.

## **6.2 Recommendations**

This research aimed to develop a new cream cheese product fortified with avocado puree to improve its nutritional values. The experiment in this project focused on the effects of avocado puree's concentrations and treatments on cream cheese's quality, stability, and sensory attributes. This project showed that different concentrations and treatments of avocado puree could significantly affect the physicochemical properties, microbial stability and sensory attributes of cream cheese. Also, adding 20% of avocado puree treated by ascorbic acid and HPP in cream cheese was recommended to develop this novel healthy cream cheese product. This is because cream cheese containing this concentration and treatment of avocado puree appeared to have better sensory attributes with less physicochemical properties change and extended shelf life, which has not been studied and reported yet in the food industry and related literature.

The physicochemical properties of avocado-fortified cream cheese, such as appearance, colour, rheological and textural properties, microbiological safety, and microstructure, were analysed and evaluated in this project over storage time. Also, a comprehensive sensory evaluation was conducted in this research. However, only one antioxidant was applied to treat avocado puree in this study. Thus, it is necessary to recommend future work to design and apply other antioxidants and some other chemical components (e.g. stabilisers, hydrocolloids, etc.) at low concentrations and their effects on avocado-fortified cream cheese. Some crucial physicochemical and sensory properties may be significantly affected by other common antioxidants.

Moreover, a relatively comprehensive sensory evaluation based on two separate sensory tests was conducted in this research. However, due to the pandemic of COVID-19, both sensory tests could only gather around less than 40 participants to do the sensory test, respectively, which could not be considered to have enough participants for a sensory evaluation. Therefore, it is necessary to recommend future work to gather more participants to join the sensory evaluation. Some critical sensory characteristics of avocado-fortified cream cheese may differ from this study if more participants take part in this particular work, such as taste, aftertaste, colour, and textural properties.

This study mainly focused on the effects of avocado puree on the physicochemical properties and sensory characteristics of cream cheese, which was formulated with avocado puree having different concentrations (0%, 10%, 20%, and 30%) and treatments (UT, ASC, HPP, and AHPP). The health benefits offered from avocado puree were not investigated in this study. Therefore, it is necessary to recommend future studies to conduct a comprehensive *in vivo* experiment to compare the health aspects between original cream cheese and avocado-fortified cream cheese.

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## Appendices

**Appendix 1. The composition of whole milk (Anchor Milk Bule Top, Fonterra Brands NZ Ltd., New Zealand) used in this study to produce cream cheese.**

<b>Component</b>	<b>Average quantity per 100 ml</b>
<b>Protein</b>	3.3 g
<b>Fat</b>	3.4 g
<b>Carbohydrate</b>	4.8 g
<b>Sodium</b>	40 mg
<b>Calcium</b>	117 mg
<b>Vitamin A</b>	43 µg
<b>Riboflavin (B2)</b>	0.2 mg

**Appendix 2. The composition of Fresh Organic Half & Half milk (Puhoi Valley, New Zealand) used in this study to produce cream cheese.**

<b>Component</b>	<b>Average quantity per 100 ml</b>
<b>Protein</b>	2.8 g
<b>Fat - Total</b>	18 g
<b>Carbohydrates</b>	3.8 g
<b>Sodium</b>	30 mg

### Appendix 3. The sensory questionnaires in the first sensory test.

1 Please rank the samples listed below, in the order that you prefer them from most to least.

Start by clicking the product code which you like MOST, followed by clicking the product code which you like SECOND, continuing until the final product code you click is the one you like LEAST.

After you make your selections the product codes will appear in the space below with the product you liked MOST on the left to the product you liked LEAST on right.

If you'd like to change the order of your responses, click the "Reset" button in the lower right-hand corner.

1	2	3	4
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RESET

2 Which of the following Sample do you think has the highest avocado content?

1	2	3	4
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

3 Which of the following Sample do you think has the least avocado content?

1	2	3	4
<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

