Effects of dried apple peel powder on the rheological and sensory properties of drinking yogurt

By
Zening Zhou

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ABSTRACT

EFFECTS OF DRIED APPLE PEEL ON THE RHEOLOGICAL AND SENSORY PROPERTIES OF DRINKING YOGURT

Zening Zhou
University of Guelph, 2018

Advisor: Dr. Gisèle LaPointe

The study was undertaken to investigate the effect of commercial dried apple peel powder (CDAP) and Granny Smith dried apple peel powder (GSAP) addition on the rheological and sensory properties of drinking yogurt in order to develop a dietary fiber enriched drinking yogurt. The rheological study showed that drinking yogurt fortified with 3.2% CDAP and 4.0% GSAP were the best-fortified amounts for drinking yogurt with the same viscosity (50 s⁻¹) and were further used to sensory evaluation. Consumer acceptance of drinking yogurt was evaluated using a 9-point consumer liking scale and a 5-point Just-About-Right scale. Consumers found that the 4.0% GSAP fortified drinking yogurt was acceptable while 3.2% CDAP fortified drinking yogurt was not accepted by consumers due to too dark color and grainy texture. These results suggest the possibility of utilizing dried apple peel powder as a dietary fiber enriched ingredient in drinking yogurt manufacture.
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LIST OF ABBREVIATIONS

GSAP .................................................................Granny Smith apple peel powder
CDAP ................................................................. Commercial dried apple peel powder
WHC ................................................................. Water holding capacity
OHC ................................................................. Oil holding capacity
SC ................................................................. Swelling capacity
LVR ................................................................. Linear Viscoelastic Region
JAR ................................................................. Just-About-Right
GAE ................................................................. Garlic Acid Equivalents
TE ................................................................. Trolox equivalents
CHAPTER 1: INTRODUCTION

Yogurt is one of many types of fermented milk products, and is the result of inoculated milk mixed with a starter culture consisting of \textit{Str. thermophilus} and \textit{Lb. delbrueckii} spp. \textit{Bulgarianus} (Tamime & Robinson, 2007). It is a well-known high nutritional value dairy product that contains active cultures. For this reason, yogurt is consumed widely around the world (Tamime & Robinson, 2007). With the development of yogurt production, yogurt varieties have increased to include fruit yogurt to meet consumers’ requirements. Drinking yogurts are a popular flavored yogurt product and are produced by diluting yogurt or fermenting diluted milk and adding fruit syrup or fruit puree (Chandan & Kilara, 2013). Lack of viscosity and syneresis are the two main challenges facing the drinking yogurt industry in the technical aspect.

Fruit by-products are regarded as dietary fiber and bioactive compounds enrichment ingredients. Many previous studies have utilized fruit by-products into yogurt manufacturing (Espírito Santo \textit{et al.}, 2013; García-Pérez \textit{et al.}, 2005; Issar, Sharma, & Gupta, 2017; Sah \textit{et al.}, 2016; Sendra \textit{et al.}, 2010; Staffolo \textit{et al.}, 2004). Fruit by-product fortification has been shown to increase the nutritional value of yogurt, especially dietary fiber. Previous studies showed that soluble dietary fiber could increase the viscosity of foods and insoluble fibers have high porosity and low density (Elleuch \textit{et al.}, 2011). O'Shea, Arendt, & Gallagher (2012) have also reported that the soluble and insoluble fiber can change the water binding abilities, gelling properties of yogurt. Oven dried passion fruit pulp powder applied to probiotic yogurts has been shown to enhance the apparent viscosity and structure of yogurt (Espírito Santo \textit{et al.}, 2013). Fortified foods with additional dietary fiber ingredient have been approved to render the texture quality (Stokes \textit{et al.}, 2013).

However, fruit by-product powders also affect the quality and sensory properties of yogurt due to particle size and dosage of the addition. Sendra \textit{et al.} (2010) have found the particle size and
Fortification dose of orange fiber has a significant impact on yogurt structure and make the solid-liquid stratification happen. Large (0.701-0.991 mm) particle fibers added to yogurt to a concentration of 0.6% and small (0.417-0.7 mm) particle fibers added to 1%, disrupt the structure of yogurt and make it nonhomogeneous and unsmooth. Elevated concentration of apple pomace powder in yogurt can increase the acidity of yogurt which can lead to decreased shelf-life and can also increase the syneresis of yogurt (Issar, Sharma, & Gupta, 2017). However, Staffolo et al., (2004) have reported that apple fiber did not affect the pH value and syneresis of yogurt. Instead, it had changed the rheological properties of plain yogurt. García-Pérez et al., (2005) showed that orange fiber had modified the color of yogurt. In addition, fortified fruit fiber can affect consumer acceptance of yogurt. Staffolo et al. (2004) have found yogurt fortified with 1.3% apple fiber turned brown and had a negative impact on consumer acceptance. Apple pomace in yogurt, at a concentration above 5%, also changed the color, flavor, and consistency of apple pomace fortified yogurt, which negatively impacted consumer acceptance (Issar, Sharma, & Gupta, 2017).

Apple peels are produced from dried apples, canned apples, applesauce, and apple pie processing. Around 2-3 million kilograms of apple peels are produced from the apple processing industry in Nova Scotia per year (Huber & Rupasinghe, 2009). The total dietary fiber content of apple peel is around 21.36% to 39.75% per dry weight (Huber & Rupasinghe, 2009). Granny Smith dried apple peels have been evaluated for their dietary fiber (39.7%) (Hentíquez et al., 2010). However, dried Granny Smith apple peel powder has not been studied as an additional dietary fiber source in fortifying drinking yogurt and how this might alter the quality and consumer acceptance of the fortified yogurt product. In this current study, apple peel was used as the additional dietary fiber ingredient due to its nutritional and economic value.
To gain a better understanding of the effects of dried apple peel powder on the quality of drinking yogurt, dried apple peel powder fortified drinking yogurt was developed for this study. The two main objectives were:

1) To evaluate the effects of dried apple peel powders on rheological properties of drinking yogurt.

2) To investigate the effects of dried apple peel powder on sensory properties of drinking yogurt.
CHAPTER 2: LITERATURE REVIEW

2.1 Yogurt

2.1.1 Yogurt introduction

Yogurt is produced by culturing dairy ingredients with *L. delbrueckii ssp. Bulgaricus* and *S. thermophiles* (Tamime & Robinson, 2007). Traditional yogurt processing mainly includes milk base preparation, homogenization, heat treatment, inoculation, fermentation, followed by cooling and storage (Tamime & Robinson, 2007). Fruit, stirred or diluted yogurt can be further processed following procedures shown in Figure 2.1.

Commercial yogurt products are categorized into set, stirred and drinkable yogurt, based on their physical texture properties. They can also be classified as plain, fruit and flavored yogurt based on flavor and as set yogurt, stirred yogurt/drinking yogurt, smoked yogurt, concentrated yogurt, frozen yogurt, yogurt drinks and beverages based on the manufacturing methods (Chandan & Kilara, 2013; Tamime & Robinson, 2007).

2.1.2 Drinking yogurt

Drinking yogurt is classified as liquid (stirred) yogurt in Canada, and has a lower viscosity compared to stirred yogurt with sugar and fruit or fruit-flavored syrups (Agriculture and Agri-Food Canada, 2016). The milk solid-non-fat (MSNF) content of white mass (yogurt component) for drinking yogurt and yogurt beverages should exceed 8.25%. This requirement is no longer necessary when flavoring ingredients are added (Chandan & Kilara, 2013; FDA, 2016). The standard fruit content of drinking yogurt ranges from 8% to 15% (Chandan & Kilara, 2013). The required sugar content of drinking yogurt is 8-12% and 8.3% for children (Chandan & Kilara, 2013; Tamime & Robinson, 2007).
In North America, drinking yogurt is typically manufactured with fruit juice and puree due to consumers’ preference for sweetness. However, the traditional drinking yogurt was invented in Turkey, named Aryan, which has a salty taste. Aryan is manufactured by adding an additional 1% salt and 30-50% water to plain yogurt without fruit flavor (Köksoy & Kiliç, 2003; Tamime & Robinson, 2007). Although there is a distinct difference in sensory attributes between salty and sweet drinking yogurt, their storage times and shelf life remains the same.

The shelf-life of drinking yogurt is 16 days at 5 °C and 10 °C and 6 days at 20 °C (Tamime & Robinson, 2007). However, syneresis is a serious problem during drinking yogurt manufacture and storage (Chandan & Kilara, 2013; Koksoy & Kilic, 2003). To solve the problem, stabilizers are
used in production. The normal usage of single or mixed hydrocolloids is 0.01-0.5% for drinking yogurt.

### 2.1.3 Yogurt nutritional value

Carbohydrates, protein, lipids, vitamin, and minerals are the main essential nutritional constituents of yogurt (Tamime & Robinson, 2007). Frias (2017) had reported 170 g low-fat fruit-flavored yogurt contributed 6% potassium and magnesium, 20-24% calcium, 26% phosphorus, 21-25% riboflavin and 30% vitamin B12 to the daily diet of an adult. Moreover, the United States Department of Agriculture (2010) suggests that people consuming low-fat fruit-flavored yogurt should ensure they are consuming enough calcium, Vitamin D, and phosphorus. Calcium and phosphorus are essential nutrients for bone development (Frias, 2017). The British Nutrition Foundation (2015) recommends consuming low-fat fruit-flavored yogurt instead of other sweets and desserts. Also, Health Canada includes yogurt in the dairy food group of the Canadian Food Guide and recommends consumers need to take at least 2 serving of yogurts (175g/serving) (Health Canada, 2016).

Apart from the nutritive constituents, consumers also can intake the active bacterial cultures/live microorganisms (lactic acid bacteria) and the bioactive components formed during fermentation from yogurt. Yogurt is required to contain at least $10^7$ CFU/g of starter culture and a minimum of $10^6$ CFU/g of labeled microorganisms. A minimum of 0.6 % of titratable acidity is required of yogurt to make sure the minimum requirements count of microorganisms, and should be expressed as the % of lactic acid. However, the regulations are different from country to country (Frias, 2017. Marette, Picard-Deland, & Fernandez, 2017; Tamime and Robinson, 2007).

The primary composition and unique live active cultures of yogurts offer health benefits to humans such as reducing the risk of type 2 diabetes, weight management and prevention of
cardiovascular disease. Additionally, lactic acid bacteria have positive effects on the immune and digestive systems and can relieve constipation, diarrheal disease, inflammatory bowel disease, Helicobacter pylori infection, and colon cancer (Frias, 2017). Lactic acid bacteria in yogurt can also ameliorate lactose intolerance. In fact, the European Food Safety Authority (EFSA) has suggested that yogurt can have a positive effect on improving lactose malabsorption (EFSA, 2010; Zare et al., 2011). Furthermore, the "Canadian Dairy Commission" emphasized that functional yogurt, such as prebiotic and probiotic yogurt, was the fastest growing sub-sectors within the yogurt industry in 2009 (CDC, 2009). Yogurt was also regarded as a potential vehicle for probiotics (Frias, 2017; Marette, Picard-Deland, & Fernandez, 2017; Tamime and Robinson, 2007). Yogurt consumption also has benefits in terms of enhancing immunity, controlling inflammation, modulating gut microbiota, and improving cholesterol metabolism (Frias, 2017; Marette et al., 2017).

In terms of its nutritional value, yogurt plays a potential role in improving human health. Fortified yogurt products should be studied in order to increase specific nutrients and prevent disease relevant to nutritional deficiencies. Different types of fortified yogurts have been researched in recent years, such as vitamins, functional ingredients, and minerals fortified yogurt (Gahruie et al., 2015).

2.1.4 Fortified yogurt

Yogurt fortified with vitamins have been reported to alleviate the nutrient gap. As we all know, Vitamin D is essential in maintaining healthy bones, but it is only photosynthesized when exposed to solar radiation. Vitamin D fortified yogurt was studied to prevent Vitamin D deficiency. However, an overdose of Vitamin D intake can lead to tissue and kidney damage (Gahruie et al., 2015). Micronutrients from natural food sources are more commonly used in fortifying yogurt
products since they contain various vitamins and minerals, are high in dietary fiber content, and contain bioactive compounds (Gahruie et al., 2015; Ozturkoglu-Budak et al., 2016).

Apart from the nutritional value of fortified yogurt, consumers also come to expect the same high yogurt quality as traditional yogurts. In order to improve the texture, viscosity, appearance, and mouthfeel of fortified yogurts, additional stabilizers are used. In recent years, stabilizers and flavoring agents from natural sources including vegetables, cereals and fruits have became more commonly used. Fresh or dried fruits and vegetables, soybean and cereals were incorporated into yogurt manufacturing in order to enhance the texture, flavor, nutritional value, and yogurt varieties (Gahruie et al., 2015).

Sakin-Yilmazer et al. (2014) produced freeze-dried yogurt powder fortified with candied chestnut puree. They found that the apparent viscosity of the end product decreased with the addition of 5% candied chestnut puree and increased with 10% and 20% candied chestnut puree. However, the candied chestnut puree had negatively impacted the color of the yogurt product. Oven-dried walnut, hazelnut, almond and pistachio powder were also incorporated in manufacturing fortified yogurt products. The folic acid, selenium, tocopherols, and omega fatty acid contents increased when fortified with 5% nut powder. The additional functional attributes did, however, compromise the products shelf-life (Ozturkoglu-Budak et al., 2016).

Fruit by-products were also repurposed as optimum ingredients used to fortify yogurt products owing to their reduced costs and nutritional benefits. Pineapple peel powder, for example, was used as a dietary fiber enhancing ingredient in yogurt (Sah et al., 2016). 1% pineapple peel powder fortification was shown to decrease the incubation time of yogurt and increased the firmness and structure of prebiotic set yogurt. However, the pineapple peel powder had aggravated the syneresis of yogurt (Sah et al., 2016). The effect of dose and particle size of orange juice by-products powder
on yogurt viscoelastic properties was studied by Sendra et al. (2010). The larger particle size had increased the viscosity of yogurt. However, at high doses, the additional dietary fiber had weakened the yogurt structure. Conversely, the smaller particle size dietary fiber from orange peels had decreased the rheological properties of yogurt as a result of the disruptive effect of fiber. However, high dose (0.6 g/100 ml) of the smaller particles compensated for the weakened yogurt structure due to the water absorption of fiber (Sendra et al., 2010).

Oven-dried passion fruit pulp powder applied to probiotic yogurts enhanced its apparent viscosity and structure (Espírito-Santo et al., 2013). 1% passion fruit pulp powder strengthened casein gels observed by field-emission scanning electron microscope. The color, odor, and appearance of fortified yogurt was also accepted by consumers however, the passion fruit flavor was weak according to consumers (Espírito-Santo et al., 2013). Citrus fiber enriched fermented milk also had good consumer acceptability (Sendra et al., 2008). However, García-Pérez et al. (2005) reported that 1% orange fiber had a negative impact on the yogurt color. Dietary fiber generated from asparagus formed a yellow-greenish color in the yogurt (Sanz et al., 2008). Hashim et al. (2009) found that dietary fiber from dates used to fortify yogurt displayed a firmer texture and was deemed acceptable by consumers as long as less than 4.5% date fiber was used. The consumers also indicated that sourness, sweetness, firmness, and smoothness of yogurt were acceptable with 3% date fiber. In the same study, yogurt fortified with 1.5% wheat fiber had a negative impact on consumer acceptability when it came to overall satisfaction. Grape skin powder fortified stirred yogurt was used to enrich the polyphenolic content and the consumer acceptance was evaluated (Marchiani et al., 2016). A 9-point hedonic scale was used and mean scores below 5 were obtained in terms of flavor, appearance, texture, odor, taste and overall liking. Consumers
also indicated that the grape skin powder enriched yogurt was too sour and not sweet, as well as having a grainy texture (Marchiani et al., 2016)

Fruit by-products can be regarded as an appropriate natural and economical ingredient in yogurt fortification as a result of their substantial dietary fiber content and bioactive content. However, fruit by-products have been shown to negatively impact textural and sensory properties of fortified yogurt and improvements must be made in order to gain consumer acceptance.

2.2 Sensory evaluation

2.2.1 Consumer acceptance test

Consumer acceptance (liking) test is a sensory test for evaluating the consumer appeal of the food products such as fortified yogurt (Espírito-Santo et al., 2013; García-Pérez et al., 2005; Hashim et al., 2009; Sakin-Yilmazer et al., 2014; Sendra et al., 2010). A hedonic scaling method is used for measuring the degree of consumer liking or disliking of products (Lawless & Heymann, 2010). A 9-point scale is the most often used in consumer acceptance test, which shown in Figure 2.2. This scaling method required consumers to have basic reading comprehension skills, visual acuity, adequate cognitive activity, and the ability to understand the 9 phrases on the scale (Ettinger, 2012). However, the acceptability scale (9-point scale) is not applicable for the evaluation of a single product because it is usually lacking a comparison baseline for consumers, and researchers cannot get enough information about the food product. Therefore, the consumer acceptance test is stronger with multiple products where the consumer acceptance can be compared between products to gain a better understanding of preference.
1. How much do you like the **Appearance** of the drinking yogurt? Check one of the option below.

<table>
<thead>
<tr>
<th>Dislike extremely</th>
<th>Dislike very much</th>
<th>Dislike moderately</th>
<th>Dislike slightly</th>
<th>Neither like or dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
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<td>□</td>
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</tr>
</tbody>
</table>

**Figure 2.2:** A 9-point scale question sample in consumer acceptance/liking questionnaire of consumer acceptance test.

### 2.2.2 Just-About-Right

The Just-About-Right (JAR) Scale is a commonly used sensory test in the food industry as it can be used by consumers to evaluate the intensity of an attribute in a food product and give a directional guidance to product developers. By combining JAR scales with consumer overall liking scales, product developers or researchers can get an integrated idea of product optimization and product consumer satisfaction (Gacula *et al.*, 2006; Lawless & Heymann, 2010; Li, Hayes, and Ziegler, 2014). Both 5-Point and 7-point scales are used to determine the intensity of critical attributes. An example of a 5-point JAR scale can be seen in **Figure 2.3**.

Please indicate your opinion about the color.

<table>
<thead>
<tr>
<th>Too light</th>
<th>Just right</th>
<th>Too dark</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

**Figure 2.3:** A Just-About-Right scale and question sample in consumer acceptance/liking questionnaire of consumer acceptance test.

The central point of the scale represents the ideal level intensity of a specific attribute in the food product that is being evaluated by consumers; it labeled as "Just right" or "Just-about-right." The two end anchors mean a specific attribute of the food product is "Too little" and "Too Much" for the consumer, such as the color of the food product is too light or is too dark (Lawless & Heymann, 2010). However, for complex attributes, like creaminess, it is hard to define the two
opposite end anchors. Therefore, for JAR scales, researchers or product developers should avoid using complex attributes, which is the limitation of using JAR scales (Lawless & Heymann, 2010).

JAR scales are often applied to optimize the critical attributes of food product and the information that is obtained can be used to re-formulate the food product. Also, when combined with a hedonic evaluation, JAR scales can provide insight on whether a specific attribute is affecting the overall product liking. However, JAR scale cannot quantify the necessary adjustment of that specific attribute.

## 2.3 Dietary fiber

Dietary fiber is defined by the US Food and Drug Administration as non-digestible carbohydrates and lignin that are intrinsic and intact in plants (FDA, 2015). In other words, dietary fiber is plant-based materials, originated from the cell walls; the primary source of dietary fiber in our diets are from fruits, vegetables, cereals and algae (Mohamed et al., 2011). Dietary fiber is classified into two groups based on its solubility in water – soluble and insoluble fiber – which is related to the polysaccharide structure. Soluble dietary fiber includes pectin substances, gums, mucilage, and some hemicelluloses; while cellulose and other types of hemicelluloses and lignin are classified as insoluble dietary fiber (Dhigra, Michael, Rajput & Patil, 2012).

During processing, dietary fiber can combine or interact with other components which can induce the production of bioavailable nutrients, or change the texture or flavor properties of the food product (Staffolo et al., 2004). Some studies show that the soluble dietary fiber can increase the viscosity of foods and decrease the glycemic response and plasma cholesterol improving the nutritional value of the food product. On the other hand, insoluble fibers have high porosity and low density, which can enhance feces bulk and reduce intestinal transit time, improving digestion (Elleuch et al., 2011). O'Shea, Arendt, & Gallagher (2012) have also reported that the soluble and
insoluble fiber can change the water binding abilities, gelling properties, and structural building abilities of food products, and in some cases, it can also be used as a fat replacement. The technological properties of dietary fiber-enriched products are related to physiological function. For example, foods enriched with dietary fiber have increased water binding capabilities, swelling, retention capacity, oil holding, gel-forming, antioxidant capacity, viscosity texturizing, and stabilizing properties (Elleuch et al., 2011).

In recent years, there has been increasing research into the health benefits of high dietary fiber food, more specifically, improving digesting capabilities and decreasing risk of many chronic diseases (O'Shea, Arendt, & Gallagher, 2012). Another potential health benefit of high fiber foods is the generation of bioactive materials in the GI tract which creates substrates for bacterial fermentation, changing the GI tract biomass and improving the GI tract flora. Moreover, the United States Food and Drug Administration has announced that a diet high in dietary fiber could help reduce the risk of cancer and coronary heart disease.

This knowledge about the health benefits of functional foods and ingredients, such as dietary fiber, has also been passed down to the consumers through both the education system and through the increased information coming from the media (Maphosa & Jideani, 2016). Consumers are becoming interested in bioactive compounds present in different foods and how they can improve human health.

Even with the increase in consumer knowledge about the health benefits of dietary fiber, Dana, King, Mainous, & Lambourne (2012) reported that the trends of mean daily dietary fiber intake had not significantly changed from 1999 to 2008 in the United States. Similarly, in Canada, the average intake of dietary fiber (17 g per day) is well below the recommended daily dietary fiber intake (38 g for men and 25 g for women daily). One option to increase daily consumption of
dietary fiber is to incorporate functional dietary fiber in fortified food products as it can also be used to improve the products physical texture. A previous study found that the most convenient and feasible way to increase the daily intake of dietary fiber is to produce dairy products fortified with dietary fiber as dairy products are consumed daily in most people’s diets (Shahidi, 2004). In this view, to enhance the nutritional values, to improve products physical texture, and to meet consumers’ requirements, the dietary fiber could be directly reused as a creative and functional dietary fiber enriched ingredient in food fortification manufacture. (Jung, Cavender & Zhao, 2015; Rupasinghe, Wang, Huber, & Pitts, 2008; Sharma et al., 2016; Sudha, Baskaran, & Leelavathi, 2006). Therefore, fortification of dietary fiber, such as that from fruit and vegetable by-products, in dairy products is a good way of increasing dietary fiber consumption.

2.4 Apple by-products

2.4.1 Apple by-products introduction

Apples (Malus domestica) are the most consumed fruit worldwide. The Agriculture and Agri-Food Canada reported that in 2012, 371 million kilograms of apples were produced in Canada in 2010. Apples are mainly used for fresh consumption and apple processing. Around 30% of apples produced in Canada from 2004 to 2014 were used for processed products such as apple juice, applesauce, solid pack apples, apple pie filling, and dried apples (AAFC, 2015). Apple juice production accounts for 65% of total processed apples. With apple pomace, apple slurry/pulp, and apple peel being the by-products generated from apple processing (Dhillon et al., 2013; Henriquez et al., 2010). Apple pomace is solid waste that is composed of the apple peel, core, seed, calyx, stem, and soft tissue, and is regarded as a valuable source of dietary fiber and polyphenol content for the nutritional, pharmaceutical, or cosmetic industry (García et al., 2009). Apple slurry/pulp is the liquid sludge waste of apple processing, and the apple peels are the waste produced from the
manufacturing processing apple items such as dried apples, apple pies, and canned apples. Dhillon et al. (2013) reported that the Canadian apple processing industry generates thousands of tons of apple pomace and apple pomace slurry every year. In 2009, it was estimated around 25,045-48,478 tons of apple pomace, and 28,590 to 57,145 tons of apple slurry were generated from apple processing industry.

Traditionally, apple by-products were dumped or used for livestock feed. Recent advances in technology about using of biochemical extraction processes have allowed the industry to utilize the organic acids, aroma compounds, bioethanol, and enzymes found in the apple by-products.

2.4.2 Apple by-products nutritional value

Apple by-products account for 25% of the whole original fruit by mass. Apple by-products are composed of water, carbohydrates, sugars, minerals, proteins, vitamins, and polyphenol compounds. Apple pomace and apple peels are two main by-products from apple processing. Apple pomace is mainly generated from apple juice processing, and contains the peel, stem, and seed of the apple. The proximate components of apple pomace are 10.80% moisture, 0.5% total ash, 2.7% total fat, 2.06% total protein, 51.10% total dietary fiber (Sudha et al., 2007). Figuerola et al. (2005) found apple pomace could be a potential dietary fiber source for supplementation in food products, indicating that Granny Smith apple pomace contained 60.7% total dietary fiber, and Royal Gala apple pomace contained 78.2% total dietary fiber. Rana et al. (2015) examined the dietary fiber content of apple pomace through different drying processes. The total dietary fiber content of seedless apple pomace ranged from 66.56% to 74.69%. Sato et al. (2011) evaluated the total dietary fiber content of oven dried eleven cultivars apple pomace, they found the total dietary fiber content of apple pomace ranged from 33.40% to 51.85%.
However, due to the inedible core, apple pomace was regarded as "waste" and not a source of value. A study by Soliman et al. (2015) found that the apple core contained several fungal species that could not be detected by the eye, some of these fungal species produced mycotoxins. Cold storage did not decrease the incidence of mycotoxins production in apples. Reusing, apple peel could be regarded as a safer apple by-product because it doesn't contain the fungi responsible for mycotoxin production in comparison the apple core.

Apple peels are the by-product generated from canned apple, dried apple, applesauce, and apple pie production, and have similar nutritional value in comparison to apple pomace. In 2003, there were 2-3 million kilograms of apple peel generated from the apple manufacturing industry in Nova Scotia, Canada (Rupasinghe, & Huber, 2008). The total dietary fiber content of dried apple peel ranges from 21.36% to 39.75% based on different varieties (Hentiquez et al., 2010; Jun et al., 2014; Rupasinghe et al., 2008). Henriqueze et al. (2010) processed Granny Smith apple peels to be used as an enrichment ingredient high in polyphenols and dietary fiber. They compared the characterization of the dried Granny Smith apple peel against fresh Granny Smith apple peels. The results showed that the total dietary fiber of dry apple peels is 47.8%, and the ratio of soluble to insoluble dietary fiber was 1:13.7. The percent of soluble dietary fiber is significant for functional and dietary properties. However, a previous study showed that the soluble-insoluble dietary fiber ratio of apple peels is around 1:2 (Figuerola et al., 2005). These contradicting results of soluble and insoluble dietary fiber ratios in Granny Smith apple peels still need to be explored. Therefore, compared to the nutritional value of apple pomace and apple pulp, apple peels are more suitable to be used as a source of dietary fiber to enrich foods.

The Canadian Food Inspection Agency (2015) has claimed that dietary fiber derived from plants, including accepted novel fibers are the primary source of dietary fiber, in food product
development. Dietary claims can be made on food products based on the dietary fiber content that the food source contributes to the product per serving size. Products can be labeled with claims such as 'dietary fiber source,' 'high dietary fiber source,' and 'really high dietary fiber source.' The added ingredient contains a total dietary fiber content of at least 2 g per serving size, the source could be applied as a dietary fiber source. For 'high dietary fiber source,' the total dietary fiber that the source contributes must be at least 4 g per serving size. A claim of ‘really high dietary fiber source’ can be used when the source contributes over 6 g of dietary fiber per serving. (Canadian Food Inspection Agency, 2015). Therefore, apple peels could be claimed as a natural dietary fiber source, high dietary fiber source, and really high dietary fiber source depending on the amount added to a food product.

2.4.3 Functional properties of apple peels

Besides the substantial amount of dietary fiber found in apple peels, apple peels were also found to be a functional ingredient in many previous studies (Wolfe & Liu, 2003). Apples are a good food source of phenolic compounds, the total extractable phenolic content of apples range from 110 to 357 mg/100 g of fresh apples (Wolfe et al., 2003). In the United States, apples were used as a source of fruit phenolics, and twenty-two percent of consumed fruit phenolic came from apples (Wolfe & Liu, 2003). Polyphenol compounds are antioxidants that could have a positive effect on preventing oxidation (Kalinowska et al., 2014). Also, Sun et al. (2002) have discovered that the more phenolic compounds an apple contains, the higher antioxidant capacity the apple has. In a study by He & Liu (2008) it was shown that the phytochemicals of apple peels had antioxidant and inhibitory activities. Free radicals could lead to oxidant damage of various molecules in the human body, which could cause many chronic diseases, like cancer, cardiovascular disease, asthma,
diabetes but are reduced by antioxidants. In the Netherlands, apples are a primary contributor of flavonol in the diet, followed by tea and onions.

Moreover, Eberhardt et al. (2000) compared the antioxidant activity of peeled and unpeeled apples. They found the antioxidant activity of both peeled apples and unpeeled apples to be very high, and both contained the capacity to inhibit human cancer cell growth based on in vitro experiments. Interestingly, the unpeeled apples have a higher antioxidant and anti-proliferative capabilities compared to the peeled apples, suggesting apple peels could be an effective functional food ingredient (Eberhardt et al., 2000). Studies suggested that apple peels be used as a dietary fiber and phytochemical enriching source, which could be used for value-added products (Huber & Rupasinghe, 2009; Wolfe et al., 2003). They found apple peel to be a strong antioxidant that could be used to control lipid oxidation. Results from a study by Huber & Rupasinghe (2009) showed the total phenolic content of 21 genotypes of apple peels ranged from 150 mg/100 g dry weight to 700 mg/100 g dry weight. The total antioxidant capacity was 16.2 to 34.1 mg GAE/100 g dry weight; with the ferric reducing antioxidant activity being 1.3 to 3.3 g TE/100 g dry weight. The oxygen radical absorbance capability of apple peels was 5.2 to 14.2 g TE/100 g dry weight, and the inhibition of methyl linoleate oxidation was 73.8% to 97.2% in apple peels of different genotypes. This data shows that apple peels could be an important natural food antioxidant (Huber & Rupasinghe, 2009). Leontowicz et al. (2003) found that the antioxidant capabilities of apple peel are significantly higher than the antioxidant capacity of apple pulp based on the higher bioactive compounds. They also found that diets fortified with apple peels had positive effects on controlling plasma lipid levels and on plasma antioxidant ability in rats. This result was also found through in-vivo testing, which showed incorporating apple peels into a human diet had a broad array of human health improvements (Leontowicz et al., 2003).
Chinnici et al. (2004) also compared the phenolic composition of apple peels to apple pulp, the total antioxidant capacity of apple peels was approximately 2.5 times higher than that of apple pulp. The main phenolic compounds found in apple peels are procyanidins, quercetin glycosides, and flavanols, all of which represent high antioxidant activity. The total antioxidant capacity was calculated using the percent decrease in 1,1-diphenyl-2-picrylhydrazyl (DPPH) model. The results showed the amount phenolic composition of apple peels is statistically correlated to the total antioxidant activity of apple peels (Chinnici et al., 2004). Therefore, apple peels could be used as a natural functional food source in new food products.

2.4.4 Apple by-products application in food manufacture

Based on the nutritional value, apple by-products can be used as a functional ingredient in food processing. Apple by-products processed into a dry fine powder can be incorporated into food production, as a source of nutrition in the manufacturing of jam, and bakery processing as an example. Previous studies have applied apple pomace or apple peel powder into bakery production to increase the nutritional value and rheological properties of baked products (Rupasinghe et al., 2008; Sudha et al., 2006).

Sudha et al. (2006) studied the effects of different levels of dried apple pomace powder (0%, 5%, 10%, 15%, 25%, 30%) on dough rheology and sensory properties in cakes. Compared to the control, the total dietary fiber content of cake fortified with 25% dried apple pomace powder improved by 13.73%, and the total phenolic content increased by 50%, proving that dried apple pomace could be used as a novel functional dietary fiber source. Compared to control, the water absorption of cakes fortified with 15% dried apple pomace powder was significantly improved by 10.5%. However, with an increase in the addition of dried apple peel powder the development time of the batter increased, and the cold viscosity and stability of the batter decreased. Sensory
properties were also altered, as the apple pomace powder led to an increase in browning as well as a grainy mouthfeel. However, panelists indicated the fruit flavor of the cake was improved with the increased use of apple pomace powder (Sudha et al., 2006). Moreover, Jun et al. (2014) also applied apple peel powder as dietary fiber enriched ingredient into cake making, and they found the cake qualities decreased when the powder was used at levels over 3 g apple peel powder per 100 g serving. Therefore, the quantity of apple by-products used in product development still needs to investigate based on acceptable sensory attributes.

Apple peel powder has also been applied to different bakery products. Rupasinghe et al. (2008) utilized two types of apple peel powder (‘Ida red’ & ‘Northern Spy’) in muffin processing. They evaluated the effects of baking on the functional and nutritional value of muffins fortified with different amounts of dried apple peel powder (0%, 4%, 8%, 16%, 24% and 32%). The results showed the apple peel powder could significantly increase the total dietary fiber content, total phenolic content, and the total antioxidant capacity of muffins. Results also indicated that apple skin could be a functional ingredient for bakery products. However, the textural properties and sensory attributes of the muffins were not investigated in this study (Rupasinghe et al., 2008).
CHAPTER 3: EFFECTS OF DRIED APPLE PEEL POWDER ON THE RHEOLOGICAL PROPERTIES OF DRINKING YOGURT

3.1 Introduction

Yogurt is one of the most consumed fermented dairy products due to its nutritional value to human health, but it lacks dietary fiber and antioxidant compounds (Marchiani et al., 2016). Yogurt fortification is defined as the supplementation of one or more nutritional components to enhance the functional properties such as the addition of dietary fiber (Ozturkoglu-Budak et al., 2016). A previous study examined fortifying yogurt with various ingredients and compounds including; minerals, polyphenols, extract fiber, cereals, dried fruit, and vegetables to improve nutritional value (Gahruie et al., 2015). However, the product still had challenges in terms of technical aspects.

Fruit dietary fiber enriched yogurt has been studied in recent years, and adding fiber to yogurt had an impact on the texture of the yogurt. Apple fiber (1.3%) fortified set yogurt showed poor compression due to the fiber aggregates when compared with a no added fiber yogurt (Staffolo et al., 2004). Moreover, adding 0.6% and 0.8% orange fiber increased the syneresis of set yogurt, while at 1% orange fiber, the fiber contributed to higher water absorption which compensated for syneresis (García-Pérez et al., 2005). On the contrary, Sah et al. (2016) found an increase in the amount of syneresis of plain yogurt fortified with 1% pineapple peel powder. The firmness of the pineapple peel powder fortified yogurt had also decreased with its addition. Apple pomace dietary fiber has been shown to decrease the acidity of yogurt with increased fiber concentrations (2.5%, 5.0%, 7.5%, 10%) (Issar, Sharma, & Gupta, 2017). Sendra et al. (2010) compared the effects of different particle sizes of orange by-products powder on the structural properties of yogurt. The
larger particle size had increased the viscosity of yogurt. However, at high doses, the additional dietary fiber had weakened the yogurt structure. On the contrary, using high doses of small fiber particles (0.417–0.7 mm), the total number of particles was higher, which also had negative effects on the yogurt's structure.

To understand the effects of dietary fiber on the rheological properties of drinking yogurt, dried apple peel powder was evaluated as a dietary fiber ingredient and applied to yogurt in this study. Apple peels were primarily generated from dried and canned apple processing and were evaluated as a food ingredient containing dietary fiber and polyphenols (Hentiquez et al., 2013). This chapter compares the effects of different dried apple peel powders used at different concentrations on the rheological properties of drinking yogurt.

3.2 Materials and Methods

3.2.1 Dried apple peel powder development

3.2.1.1 Samples

Granny Smith apples (Product number: 20253488001_KG) purchased from local supermarket (Zehrs, Guelph, Ontario, Canada) were used to make apple peel powder. The Granny Smith apple peel powder was evaluated against AppleActiv DDAP™, a commercial dried apple peel powder (CDAP) obtained from AppleActiv company (a trademark of Leahy Orchards).

3.2.1.2 Granny Smith dried apple peel powder preparation

The Granny Smith apples were suspended in water for 5 mins and washed. Granny Smith apples were peeled after drying. Henriquez et al. (2013) reported that apple peels are prone to polyphenol oxidase (PPO) activity, which has a negative effect on the level of antioxidant compounds. To prevent enzymatic browning and preserve the phenolic content, the peels were soaked in boiling water for 10 s immediately after peeling (Wolfe & Liu, 2013a). After blanching, the peels were
transferred into cold water quickly for 10 s to avoid further degradation. Then, the peels of five apples were packed into a Ziploc® brand freezer bag and frozen at -80 °C in the freezer for 2 h. The frozen peels were dried in a freeze drier (Virtis Genesis, SP Scientific, Inc) at the Department of Food Science, University of Guelph. The condenser temperature of the freeze drier was set to -40 °C, the shelf temperature was set at 25 °C, and the vacuum was set to 150 μm for 72 hours (Wolfe & Liu, 2003). Each drying trial was performed in triplicate. The Granny Smith apple peels were ground by the UDY cyclone sample mill (UDY Corporation, Fort Collins, Co 80524), and a 30-0303 0.5 mm mesh steel screen was used. The ground dried apple peel powder was packed into Ziploc® brand freezer bags and stored at -30 °C.

3.2.3 Determining the proximate composition of dried apple peel powder

3.2.3.1 Moisture

The moisture content of GSAP and CDAP was analyzed using the modified AOAC standard method 926.08 (AOAC, 2000). Crucibles and lids were pre-dried in the oven until a constant weight was obtained. Approximately 5 g of dried apple peel powder was weighed into the crucible, and loosely covered with the lid. The covered crucibles were then placed in the vacuum oven, and kept at 60-70 °C for 6 hours. When the samples dried to a constant weight, they were put into the desiccator to cool, and the moisture content was calculated by weight loss. Three independent tests were conducted for each sample.

3.2.3.2 Ash

The ash content was analyzed based on the modified AOAC method 940.26 (AOAC, 2000). Using the dried sample from the moisture analysis the crucibles containing the samples were placed into the muffle furnace, kept at 550 °C and left until the sample turned to white ash.
(approximately 6 h). The crucibles were then immediately placed into a desiccator to cool. The ash content was calculated by weight. Three independent tests were conducted for each sample.

3.2.3.3 pH

The pH of GSAP and CDAP was determined using AOAC method 981.12 (AOAC, 2000). 2 g dried apple peel powder was weighed and suspended in 98 mL distilled water in a flask. The sample was stirred until the sample was fully suspended and no lumps aggregated (15 min). The suspension stood for 2 h. The pH meter was calibrated using pH=4 and pH=7 buffers, and then submersed into the supernatant liquid in order to measure the pH value of the sample. Three independent tests were conducted for each sample.

3.2.3.4 Protein

The protein content of GSAP and CDAP was analyzed using the combustion method by a nitrogen analyzer (Dumas, FP-528 Leco Instrument Ltd. Mississauga, ON, Canada). The Ethylenediaminetetraacetic acid (EDTA) (% N 9.56 ± 0.02) with known nitrogen content was used as the nitrogen calibration standard before running the dried apple peel powders samples. 0.2 g samples were weighed in a tin cup and wrapped up with aluminum foil. The sample was put on the loading dock. Samples combustion happened in a 1150 °C sealed furnace. The factor of conversion between nitrogen and protein was 6.25 for fruit flours (O’Shea et al., 2015). Three independent tests were conducted for each sample.

3.2.3.5 Color

The color of GSAP and CDAP was determined by a Konica Minolta CM-3500d spectrophotometer (Konika Minolta Sensing, Inc., New Jersey, USA) equipped with a SpectraMagic NX CM-S100. White calibration plate (CM-A120) and zero calibration box (CM-A124) were used to calibrate the instrument before analyzing samples. 3 g dried apple peel powder
was weighed into a petri dish (CM-A126) The spectral parameters used were lightness (L*), greenness/redness (a*), and blueness/yellowness (b*) (Yang, 2016).

3.2.3.6 Water Activity

Water activity (a_w) of GSAP and CDAP was determined based on the chilled-mirror dew-point technique using a water activity analyzer (Aqua Lab 4TE, Decagon Devices, USA). 2 g of dried apple peel powder was weighed into the sample cup and placed in the sample chamber. The water activity of sample represents the energy status of water in a system. A fan, a dew point sensor, a temperature sensor and an infrared thermometer were inside the chamber and used to determine the value. The test was conducted in triplicate for each sample.

3.2.3.7 Particle Size and distribution

The particle size distribution of GSAP and CDAP was determined by the Static light scattering instrument (Mastersizer 2000, Malvern Instruments Ltd Worcestershire, UK), which was equipped with a small volume entry level wet dispersion unit (Hydro 2000 SM) with a stirrer. 1 g of dried apple peel powder was diluted into 50 mL 2-propanol first. A few drops of the diluted dried apple peel sample were added to the wet dispersion unit and stirred at 1900 rpm until an appropriate obscuration (80 ± 2%) was reached, which means the blue laser obscuration bar showed a green light. The optical bench contains many individual detectors, and each detector obtains the light scattering from a particular range of angles. When the samples went through the analyzer laser beam, the array detectors start to take “snapshots” and calculate the average result. The data were analyzed by the Malvern software 2000. The test was conducted in triplicate for each sample.

An optical model theory; Mie theory, was used to predict the way light is scattered by spherical particles and measure the light that the particles absorbed by using the followed conditions: particle refractive index 1.45, refractive index if dispersant (2-propanol) 1.38, particle absorption index 0.
The volume-weighted mean diameter \([D (4,3)]\) and the surface-weighted mean diameter \([D (3,2)]\) were determined. The statistics of the particle size and distribution were calculated from the data using the derived diameters \(D [m, n]\):

- \(D [v, 0.5]\): means 50% volume of the sample particles’ diameter is smaller than the size \(D [v, 0.5]\) in microns and 50% of the sample’s particle size is bigger than the derived diameter \(D [v, 0.5]\).
- \(D [v, 0.9]\): means 90% of the volume of the sample particle diameter is below the derived diameter \(D [v, 0.9]\).

### 3.2.3.8 Fat

The fat content of GSAP and CDAP were determined by AOAC method 954.02 (AOAC, 2000). This evaluation was done by SGS Agriculture and Food Canada Inc. (Guelph, Ontario, Canada). Three independently test was conducted for each sample.

### 3.2.3.9 Dietary fiber

The soluble dietary fiber, insoluble dietary fiber and total dietary fiber content of GSAP and CDAP were determined by AOAC method 991.43 (AOAC, 2000). This evaluation was done by SGS Agriculture and Food Canada Inc. (Guelph, Ontario, Canada). Three independent tests were conducted for each sample.

### 3.2.3.10 Total sugar

The total sugar content of GSAP and CDAP were determined by AOAC method 982.14 (AOAC, 2000). This evaluation was done by SGS Agriculture and Food Canada Inc. (Guelph, Ontario, Canada). Three independently test was conducted for each sample.
3.2.3.11 Total phenolic content

The total phenolic content of GSAP and CDAP were determined by the method modified from Chen et al. (2015). The powders were weighed (1.0 g) and extracted in 15 mL of 70% MeOH containing 1% HCl (v/v) by vortexing for 10 s using a vortex mixer. Then 15 mins ultra-sonication was done by an ultrasonic cleaner, and 2 h rotational mixing was done by a rotator mixer at room temperature. The supernatant of the extraction mixture was collected after centrifugation at 4500g for 10 mins, and the extraction was repeated in triplicates. The supernatant containing solvent-solubilized compounds were combined and referred to as the crude extract and later used for the TPC assay. The extraction was done in triplicates (Chen et al., 2015) and the test was conducted in triplicates for each sample.

Folin–Ciocalteu assay was employed to determine the TPC of GSAP and CDAP extracts using a UV/Vis Biotek Powerwave XS2 microplate reader measuring at 750 nm. A standard curve was generated using a range of authentic Gallic acid standards (GA; 5 mg/mL; \( r^2 = 0.99 \)). Controls included the measurement of TPC in the absence of phenol reagent and blanks to account for the extracting solvent. TPC was expressed as a milligram of Gallic acid equivalents per gram GSAP (mg GAE/g). The measurement was compared to a standard curve of Gallic acid concentrations and expressed as mg Gallic acid equivalents/g (Chen et al., 2015; Wolfe et al., 2003). The test was conducted in triplicates for each sample.

3.2.4 Functional properties of dried apple peel powders

3.2.4.1 Water retention capacity

Water holding capacity (WRC) of GSAP and CDAP were determined by the method modified from Rana et al. (2015). 1 g dried apple peel powder was weighed and added to a 15 mL pre-weighted centrifuge tube with 10 mL of distilled water. The suspension was mixed using a Corning
vortex mixer for 30 s and allowed to stand at room temperature for 1 h. Thereafter, samples were centrifuged (15 m, 3,000 × g) and the supernatant liquid was discarded. The final weight of the sample and tube was recorded. The WHC is defined as the volume of water retained by 1 g dried apple peel powder (mL/g dry matter) under certain soaking and centrifugation conditions. The WRC test was conducted in triplicate for each sample.

3.2.4.2 Oil holding capacity

The oil holding capacity (OHC) of GSAP and CDAP were analyzed by the method modified from Rana et al. (2015). 1 g dried apple peel powder was weighed into a pre-weighed 15 mL centrifuge tube with 10 mL soybean oil. Samples were mixed using a corning vortex mixer for 30 s and stood for 30 m at 25 ± 2°C without disturbance. Thereafter tubes were centrifuged for 25 mL at 4,000 rpm, and supernatant oil was decanted. The final weights of the samples and tubes were recorded. Oil holding capacity of dried apple peel powder was calculated as grams of oil retained per gram of sample (g/g dry matter) under certain centrifuge conditions. The test was run in triplicate for each sample.

3.2.4.3 Swelling capacity (SWC)

Swelling capacity of GSAP and CDAP was determined by the method modified from Rene et al. (2015). 1 g of dried apple peel powder was placed in a 15 mL graduated centrifuged tube with 10 mL distilled water. Samples were hydrated for 18 h in the tube. The swelling capacity of dried apple peel powder was calculated as the final volume attained of the samples by per gram sample (mL/g). The formulation is:

\[
\text{Swelling Capacity (mL/g)} = \frac{\text{Volume occupied by sample (mL)}}{\text{Original sample weight (g)}}
\]

The test was conducted in triplicate for each sample.
3.2.5 Drinking yogurt development

3.2.5.1 Ingredients of drinking yogurt

The serving size of drinking yogurt is 250 mL, as suggested by the government of Canada (2016). The ingredients of drinking yogurt were skim milk, skim milk powder, sugar, water, high methoxyl (HM) pectin and low methoxyl (LM) pectin (Modernist Pantry), dried apple peel powders (CDAP & GSAP), and active yogurt culture (Thermophilic YoFlex® culture, Chr. Hansen).

3.2.5.2 Formulation development

The total dietary fiber content of GSAP was determined to be 21.53%, and the total dietary fiber content of CDAP was 41.93%. Based on the requirement of dietary fiber enriched food products, the food product must contain at least 2 g total dietary fiber per serving. The lowest concentration of CDAP and GSAP used in drinking yogurt was 1.7% and 3.5% per serving.

3.2.5.3 Milk base preparation

4 L of skim milk was used and contained 9.5% total solid content. The total solid content would increase to 1.5% after heat treatment (Tamime & Robinson, 2007). To make the milk base, skim milk was mixed with 3% skim milk powder, 1% sugar, 0.1% low-methoxyl (LM) pectin to make the total solid content 15.1% (Tamime & Robinson, 2007).

Moreover, Virk. & Sogi (2004) reported the pectin content of apple peels to be 1.5%, so an estimation that GSAP and CDAP contained 1.5% pectin was made. The pectin content of the drinking yogurt was accounted for by reducing the 1.5% amount based on the original pectin content (0.3%). The total sugar content of GSAP and CDAP was 46.67% and 22.83% respectively. The sugar content used in drinking yogurt was adjusted by reducing the total sugar content of GSAP and CDAP based on the original total sugar content of drinking yogurt (9%). Based on the
The determination of the ingredients above, the yogurt product formulation is shown in **Table 3.1**, **Table 3.2**, and **Table 3.3**.

**Figure 3.1**: Drinking yogurt manufacture procedure
3.2.5.4 Fruit mix preparation

Dried apple peel powder, sugar, and high-methoxyl (HM) pectin were mixed uniformly. Water was added and mixed homogeneously for 5 mins using a blender. The fruit mix was stored at 4 °C for 12 h (Chandan & Kilara, 2013).

3.2.5.5 Yogurt preparation

The preparation of drinking yogurt was done as shown in Figure 3.1. the milk-base was heated at 85 °C for 30 m, and then cooled to 42.5 °C. Yogurt culture was added (250 L/50U), and fermentation was conducted at 42.5 °C for 5 h. When the pH of yogurt reached 4.6, the fermentation process was stopped. Then the yogurt was cool down to 4 °C, and stored for 12 h. the prepared fruit mix was then added to the yogurt and mixed for 50 s using a hand blender.

3.2.6 Yogurt manufacture parameters evaluation

3.2.6.1 pH

The pH of drinking yogurt was measured after 12 h of manufacturing and was measured by a pH meter based on the AOAC method 981.12 (AOAC, 2000). The test was conducted in triplicate for each sample.

3.2.6.2 Titratable Acidity

The titratable acidity (TA) of drinking yogurt was determined using a 902 Titrando (Metrohm AG, CH-9100 Herisau, Switzerland). The 902 Titrando instrument was controlled by tiamo PC software. 0.1 mol/L NaOH was used as the titrant to reach the titration pH = 8.3. 5 g drinking yogurt sample was weighed in a centrifuge and diluted by 15 mL CO₂-free water to make a 20 mL test solution. The test sample was put into the stirrer container of the machine, and the stirring rate was set to level 8. The maximum rate was 10 mL/min, and the minimum rate was 25 μL/min. The stop drift was 20 μL/min. The test was conducted in triplicate, individually for each sample. The
titratable acidity was reported as % lactic acid by weight; $1 \text{ mL } 0.1 \text{ M NaOH} = 0.0090 \text{ g lactic acid}$.

Table 3.1: Formulation of drinking yogurt with 50% yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ingredients</th>
<th>Yogurt (%)</th>
<th>HM Pectin (%)</th>
<th>Sugar (%)</th>
<th>GSAP/DDAP (%)</th>
<th>Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td></td>
<td>50</td>
<td>0.30</td>
<td>9</td>
<td>0</td>
<td>40.70</td>
</tr>
<tr>
<td>CD24</td>
<td></td>
<td>50</td>
<td>0.26</td>
<td>8.4</td>
<td>2.4</td>
<td>38.94</td>
</tr>
<tr>
<td>CD32</td>
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<td>50</td>
<td>0.26</td>
<td>8.2</td>
<td>2.8</td>
<td>38.74</td>
</tr>
<tr>
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<td>38.55</td>
</tr>
<tr>
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<td>0.25</td>
<td>7.8</td>
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<td>38.35</td>
</tr>
<tr>
<td>GS40</td>
<td></td>
<td>50</td>
<td>0.25</td>
<td>7.1</td>
<td>3.2</td>
<td>39.45</td>
</tr>
<tr>
<td>GS48</td>
<td></td>
<td>50</td>
<td>0.25</td>
<td>6.7</td>
<td>3.6</td>
<td>39.45</td>
</tr>
</tbody>
</table>

Table 3.2: Formulation of drinking yogurt with 60% yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ingredients</th>
<th>Yogurt (%)</th>
<th>HM Pectin (%)</th>
<th>Sugar (%)</th>
<th>GSAP/DDAP (%)</th>
<th>Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td></td>
<td>60</td>
<td>0.30</td>
<td>9</td>
<td>0</td>
<td>30.70</td>
</tr>
<tr>
<td>CD24</td>
<td></td>
<td>60</td>
<td>0.26</td>
<td>8.4</td>
<td>2.4</td>
<td>28.94</td>
</tr>
<tr>
<td>CD32</td>
<td></td>
<td>60</td>
<td>0.26</td>
<td>8.2</td>
<td>2.8</td>
<td>28.74</td>
</tr>
<tr>
<td>CD40</td>
<td></td>
<td>60</td>
<td>0.25</td>
<td>8.0</td>
<td>3.2</td>
<td>28.55</td>
</tr>
<tr>
<td>CD48</td>
<td></td>
<td>60</td>
<td>0.25</td>
<td>7.8</td>
<td>3.6</td>
<td>28.35</td>
</tr>
<tr>
<td>GS40</td>
<td></td>
<td>60</td>
<td>0.25</td>
<td>7.1</td>
<td>3.2</td>
<td>29.45</td>
</tr>
<tr>
<td>GS48</td>
<td></td>
<td>60</td>
<td>0.25</td>
<td>6.7</td>
<td>3.6</td>
<td>29.45</td>
</tr>
</tbody>
</table>

Table 3.3: Formulation of drinking yogurt with 70% yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ingredients</th>
<th>Yogurt (%)</th>
<th>HM Pectin (%)</th>
<th>Sugar (%)</th>
<th>GSAP/DDAP (%)</th>
<th>Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td></td>
<td>70</td>
<td>0.30</td>
<td>9</td>
<td>0</td>
<td>20.70</td>
</tr>
<tr>
<td>CD24</td>
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<td>70</td>
<td>0.26</td>
<td>8.4</td>
<td>2.4</td>
<td>28.94</td>
</tr>
<tr>
<td>CD32</td>
<td></td>
<td>70</td>
<td>0.26</td>
<td>8.2</td>
<td>2.8</td>
<td>28.74</td>
</tr>
<tr>
<td>CD40</td>
<td></td>
<td>70</td>
<td>0.25</td>
<td>8.0</td>
<td>3.2</td>
<td>28.55</td>
</tr>
<tr>
<td>CD48</td>
<td></td>
<td>70</td>
<td>0.25</td>
<td>7.8</td>
<td>3.6</td>
<td>28.35</td>
</tr>
<tr>
<td>GS40</td>
<td></td>
<td>70</td>
<td>0.25</td>
<td>7.1</td>
<td>3.2</td>
<td>29.45</td>
</tr>
<tr>
<td>GS48</td>
<td></td>
<td>70</td>
<td>0.25</td>
<td>6.7</td>
<td>3.6</td>
<td>29.45</td>
</tr>
</tbody>
</table>
3.2.6.3 Color

The color of drinking yogurt was measured after making 12 hours and was determined by a Konica Minolta CM-3500d spectrophotometer (Konika Minolta Sensing, Inc., New Jersey, USA). The test conducted in triplicate individually for each sample.

3.2.6.4 Water holding capacity

The water holding capacity of drinking yogurt was determined by the method reported previously with a modified centrifuge speed (Pang et al., 2017). Drinking yogurt was measured in 10 mL centrifuge tubes and were centrifuged at 2400 g for 10 mins at 4 °C. The water-holding capacity (WHC) of drinking yogurt was calculated as follows:

\[
\text{WHC (\%)} = \frac{100(\text{DY weight} - \text{SE weight})}{\text{DY weight}}
\]

DY = drinking yogurt weight and SE = serum expelled; Three independent tests were run for each sample.

3.2.6.5 Syneresis

The serum separation of drinking yogurt was measured by the method under influence of regular gravity, which was modified from the previous study (Koksoy & Kilic, 2004). 10 mL drinking yogurt sample were placed in 10 mL graduated cylinder and stored at 4 °C for 16 days. The volume of separated liquid was recorded and reported as mL/ 10 mL. Three independent tests were run for each sample.
3.2.7 Rheological properties of yogurt

3.3.7.1 Viscosity characterization

The viscoelastic properties and the apparent viscosity of drinking yogurt were determined by the method modified from the previous study (Hess, Roberts, & Ziegler, 1997; Koksoy & Kilic, 2004). The drinking yogurt samples were measured right after making to reduce the effects of sample shear history. Tests were conducted using an Anton Paar Physica MCR 301 controlled stress rheometer (Anton Paar Germany GmbH, Ostfildern, Germany) with a measuring cell (P-PTD 120) equipped with a Peltier temperature control. A humidity chamber was used to prevent water loss during evaluation. A Julabo circulator (JulaboWest, Inc., CA, USA) was used as a temperature control system for the Peltier element. A parallel plate geometry (PP50) was used at 0.5 mm gap. The test was conducted at 4 °C.

The flow behavior and apparent viscosity of drinking yogurt was determined by the controlled ramped shear rate sweep test. The shear rate (\( \dot{\gamma} \)) was increased from 0.13 to 300 s\(^{-1}\) in 5 min (upward curve) and decreased to 0.13 s\(^{-1}\) from 300 s\(^{-1}\) (downward curve). Shear stress (\( \sigma \)) and viscosity (\( \eta \)) changed by shear rate changing (Hess, Roberts, & Ziegler, 1997). The shear stress-shear rate of the sample was plotted on logarithmic coordinates, which is fit to the Power Law Model. The model obtained the flow behavior of sample, such as shear thinning fluid and shear thickening fluid. The power law model function was followed:

\[
\text{Power law: } \tau = K (\dot{\gamma})^n
\]

K-consistency (Pa \( \cdot \) s); n-powder law index, which reflected the closeness to Newtonian flow; \( n<1 \), means the sample is a shear thinning fluid; \( n>1 \), means the sample is shear thickening fluid; \( n=1 \), means the sample is Newtonian fluid (Rao, 2014). The test was conducted in triplicate for each sample.
3.2.7.2 Viscoelastic properties of drinking yogurt

The viscoelastic properties of drinking yogurt were determined by strain and stress sweep tests. The test was conducted at a constant frequency of 1 Hz, and strain amplitude ranging from 0.1 to 1000 %. Storage modulus (G’) and loss modulus (G’’) were evaluated by the changing of shear strain. The yield point (τ_y) and flow point (τ_f) were obtained from the continuous stress amplitude sweep. G’ and G’’ were plotted by shear stress changing, and the cross point (G’=G’’) was taken as the flow point. The flow point was related to breaking the internal structure and start to flow. (Hess, Roberts, & Ziegler, 1997). The yield point was considered as the maximum value of Liner viscoelastic region (LVR) and showed the structure started to rupture. The test was conducted in triplicate for each sample.

3.2.8 Final drinking yogurt formulation selection

The final formulation of drinking yogurt was selected by the apparent viscosity at 50 s\(^{-1}\) of all samples. Based on the requirements of processing parameters, the apparent viscosity of drinking yogurt/yogurt drinks should be 0.200 to 0.500 (Pa \(\cdot\) s). When the apparent viscosity of yogurt sample is over 1.500 (Pa \(\cdot\) s), the yogurt is classified as a stirred yogurt (PCM, 2017).

3.2.9 Statistic analysis

Statistical analysis for yogurt properties and rheological properties were performed using one-way ANOVA and Tukey post-hoc test. All the data was analyzed by GraphPad Prism 5.0 (GraphPad Software, San Diego, CA, US). A 95% confidence interval was considered in the test (p < 0.05).
3.3 Results

3.3.1 Proximate compounds analysis of dried apple peel powder

The physicochemical parameters and the content of total dietary fiber, sugar, and total phenolic content of GSAP and CDAP are shown in Table 3.4. The moisture, fat, carbohydrate, and ash contents of GSAP and CDAP were similar. However, compared with CDAP, the protein content, pH, and water activity of GSAP were much lower. Over 90% of the CDAP particle sizes were 0.79 mm, which was bigger than the particle size of GSAP (0.17 mm). The total dietary fiber of CDAP and GSAP were 41.93% and 21.53% by dry mass, respectively. From the results, the dietary fiber content of CDAP was almost twice as high as GSAP. Additionally, the soluble dietary fiber content of both CDAP and GSAP was similar. However, the insoluble dietary fiber content of CDAP was 2.3 times higher than that of GSAP. The soluble-insoluble ratio of dietary fiber for both GSAP and CDAP were calculated, and the ratios were 0.57 and 0.31 respectively.

![Image of two powdered samples]

**Figure 3.2:** Granny Smith apple peel powder (left) and commercial dried apple peel powder (right)
Table 3.4: Proximate components of dried apple peel powder

<table>
<thead>
<tr>
<th>Attributes</th>
<th>GSAP</th>
<th>CDAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>2.37 ± 0.02</td>
<td>2.83 ± 0.04</td>
</tr>
<tr>
<td>Fat (%)</td>
<td>2.18 ± 0.16</td>
<td>2.52 ± 0.14</td>
</tr>
<tr>
<td>Carbohydrate (%)</td>
<td>89.97 ± 0.39</td>
<td>87.43 ± 0.14</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.93 ± 0.02</td>
<td>1.73 ± 0.04</td>
</tr>
<tr>
<td>Protein (%)</td>
<td>3.35 ± 0.12</td>
<td>5.49 ± 0.07</td>
</tr>
<tr>
<td>pH</td>
<td>3.92 ± 0.05</td>
<td>5.12 ± 0.01</td>
</tr>
<tr>
<td>Water Activity</td>
<td>0.12 ± 0.00</td>
<td>0.40 ± 0.00</td>
</tr>
<tr>
<td>Particle Size (mm)</td>
<td>0.17 ± 0.16</td>
<td>0.79 ± 0.19</td>
</tr>
<tr>
<td>Insoluble dietary fiber (%)</td>
<td>13.73 ± 0.93</td>
<td>32 ± 0.61</td>
</tr>
<tr>
<td>Soluble dietary fiber (%)</td>
<td>7.83 ± 0.15</td>
<td>9.97 ± 0.23</td>
</tr>
<tr>
<td>Total dietary fiber (%)</td>
<td>21.53 ± 1.10</td>
<td>41.93 ± 0.78</td>
</tr>
<tr>
<td>Total Sugar (%)</td>
<td>46.67 ± 2.34</td>
<td>22.83 ± 0.76</td>
</tr>
<tr>
<td>Total Phenolic Content (mg GAE/ g)</td>
<td>18.00 ± 0.30</td>
<td>12.54 ± 0.11</td>
</tr>
<tr>
<td>Color Parameters</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a*</td>
<td>-2.27 ± 0.03</td>
<td>7.05 ± 0.06</td>
</tr>
<tr>
<td>b*</td>
<td>30.72 ± 0.04</td>
<td>23.35 ± 0.33</td>
</tr>
<tr>
<td>L*</td>
<td>75.92 ± 0.05</td>
<td>68.23 ± 0.13</td>
</tr>
</tbody>
</table>

Foot notes:
- GSAP: Granny Smith apple peel powder; CDAP: Commercial dried apple peel powder
- a* redness; b* yellowness; L* lightness

Moreover, the total sugar contents of GSAP and CDAP were different, which is opposite of the results of the total dietary fiber content. The total sugar content of GSAP was 46.67%. The total phenolic content (TPC) of GSAP (18.00 mg GAE/g) was higher than that of CDAP (12.45 mg GAE/g). Figure 3.2 Shows the difference in colour visually of GSAP and CDAP. Combined with the data of color parameters shown in Table 3.4. The CDAP was redder, and the GSAP was greener.

3.3.2 Functional properties of dried apple peel powders

The functional properties of GSAP and CDAP results are shown in Table 3.5. The water retention capacity (WRC) of GSAP was 2.82 g water/ g dry weight, which was a little lower than that of CDAP (3.84 g water/ g dry weight). The oil holding capacity (OHC) of GSAP was 1.52 g
oil/g dry weight, which was higher than the OHC of GSAP (1.18 g oil/g dry weight). Additionally, there was no significant difference in the swelling capacity of both GSAP and CDAP.

Table 3.5: Functional properties of apple peel powder

<table>
<thead>
<tr>
<th>Functional Properties</th>
<th>GSAP</th>
<th>CDAP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Retention Capacity (g water / g DW)</td>
<td>2.82 ± 0.04</td>
<td>3.84 ± 0.09</td>
</tr>
<tr>
<td>Oil Holding Capacity (g oil / g DW)</td>
<td>1.52 ± 0.08</td>
<td>1.18 ± 0.02</td>
</tr>
<tr>
<td>Swelling Capacity (mL water / g DW)</td>
<td>10.77 ± 0.15</td>
<td>10.78 ± 0.03</td>
</tr>
</tbody>
</table>

Foot notes:
- GSAP: Granny Smith apple peel powder; CDAP: Commercial dried apple peel powder

3.3.3 Viscosity of yogurt

The upward flow curve shear rate and shear stress data set used to fit the Power Law model. The parameters of flow behavior and apparent viscosity for all yogurt samples are shown in Table 3.6, Table 3.7, and Table 3.8, which includes the consistency coefficient (κ), flow behavior index (n), R² for model fitting, and the apparent viscosity at the shear rate 50⁻¹s (η). From Table 3.8, the flow behavior curves of most 50% yogurt samples had an adequate fit to the Power Law Model (R² > 0.98) except the C48 (R²=0.97) sample. The 70% yogurt formulation, G40 (R²=0.81) and G48 (R²=0.84) flow curves were not fit to the Power Law Model, whereas the flow curves of other yogurt samples fortified with CDAP were fitted to the model. The flow curve of the samples made with 60% yogurt formulation were also not adequate to the Power Law Model. Therefore, based on the flow behavior model fitting results, the 70% yogurt formulation was applicable for CDAP only, and the 50% yogurt formulation was best suitable for both GSAP and CDAP application.

The apparent viscosity of the 70%, 60% and 50% yogurt samples is shown in Table 3.6, Table 3.7 and Table 3.8. The apparent viscosity of the 70% yogurt samples fortified with dried apple peel powders ranged from 0.838 to 1.270 Pa • s, which does not meet the required apparent viscosity of drinking yogurt. The apparent viscosity of the 50% yogurt samples ranged from 0.395
to 0.553 Pa • s, and the apparent viscosity increased with dried apple peel powder increasing in both CDAP and GSAP. With applying the same amount of GSAP and CDAP, the 50% drinking yogurt fortified with CDAP had a higher viscosity. The apparent viscosity of CD24, CD32, and GS40 showed no significant difference, and there was also no significant difference in apparent viscosity between CD40 and CD48. Moreover, samples CD32 and GS40 exhibited the same apparent viscosity.

Based on Table 3.8, the flow behavior indexes of all flow curves for the 50% yogurt formulation were all <1. All the yogurts made using the 50% yogurt formulation were shown to have shear thinning and time-dependent properties.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Consistency coefficient (K, Pa • s⁻¹)</th>
<th>Flow behavior index (n)</th>
<th>R²</th>
<th>Apparent viscosity at 50s⁻¹ (Pa • s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>8.68 ± 0.34</td>
<td>0.30 ± 0.01</td>
<td>0.99 ± 0.00</td>
<td>0.55 ± 0.02ᵃ</td>
</tr>
<tr>
<td>CS24</td>
<td>14.05 ± 1.17</td>
<td>0.28 ± 0.01</td>
<td>0.99 ± 0.00</td>
<td>0.84 ± 0.03ᵇ</td>
</tr>
<tr>
<td>CS32</td>
<td>17.29 ± 2.09</td>
<td>0.27 ± 0.03</td>
<td>0.99 ± 0.02</td>
<td>0.77 ± 0.03ᵇｃ</td>
</tr>
<tr>
<td>CS40</td>
<td>19.89 ± 1.94</td>
<td>0.26 ± 0.01</td>
<td>0.99 ± 0.01</td>
<td>1.10 ± 0.07ᶜᵈ</td>
</tr>
<tr>
<td>CS48</td>
<td>23.40 ± 2.17</td>
<td>0.25 ± 0.03</td>
<td>0.98 ± 0.01</td>
<td>1.24 ± 0.06ᵈᵉ</td>
</tr>
<tr>
<td>GS40</td>
<td>39.53 ± 4.93</td>
<td>0.11 ± 0.02</td>
<td>0.81 ± 0.06</td>
<td>1.27 ± 0.08ᶜ</td>
</tr>
<tr>
<td>GS48</td>
<td>37.87 ± 3.94</td>
<td>0.13 ± 0.02</td>
<td>0.84 ± 0.02</td>
<td>1.27 ± 0.06ᶜ</td>
</tr>
</tbody>
</table>

Footnotes:
- Different letters mean a significant difference (P<0.05)
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
Table 3.7: Flow behavior of 60% yogurt containing different concentration of GSAP & CDAP at different level

<table>
<thead>
<tr>
<th>Sample</th>
<th>Consistency coefficient (K, Pa • s^n)</th>
<th>Flow behavior index (n)</th>
<th>R^2</th>
<th>Apparent viscosity at 50s⁻¹ (Pa • s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>4.96 ± 1.13</td>
<td>0.36 ± 0.05</td>
<td>0.98 ± 0.01</td>
<td>0.39 ± 0.02^a</td>
</tr>
<tr>
<td>CD24</td>
<td>8.75 ± 1.16</td>
<td>0.33 ± 0.04</td>
<td>0.97 ± 0.02</td>
<td>0.63 ± 0.04^b</td>
</tr>
<tr>
<td>CD32</td>
<td>10.13 ± 0.91</td>
<td>0.32 ± 0.02</td>
<td>0.97 ± 0.01</td>
<td>0.72 ± 0.05^b</td>
</tr>
<tr>
<td>CD40</td>
<td>14.06 ± 1.40</td>
<td>0.29 ± 0.02</td>
<td>0.95 ± 0.01</td>
<td>0.89 ± 0.02^c</td>
</tr>
<tr>
<td>CD48</td>
<td>18.14 ± 1.01</td>
<td>0.27 ± 0.02</td>
<td>0.95 ± 0.01</td>
<td>1.04 ± 0.01^d</td>
</tr>
<tr>
<td>GS40</td>
<td>18.68 ± 3.25</td>
<td>0.20 ± 0.03</td>
<td>0.93 ± 0.03</td>
<td>0.83 ± 0.06^c</td>
</tr>
<tr>
<td>GS48</td>
<td>24.68 ± 3.07</td>
<td>0.17 ± 0.02</td>
<td>0.89 ± 0.02</td>
<td>0.95 ± 0.06^c</td>
</tr>
</tbody>
</table>

Foot notes:
- Different letters mean a significant difference (P<0.05)
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP

Table 3.8: Flow behavior of 50% yogurt containing different concentration of GSAP & CDAP at different level

<table>
<thead>
<tr>
<th>Sample</th>
<th>Consistency coefficient (K, Pa • s^n)</th>
<th>Flow behavior index (n)</th>
<th>R^2</th>
<th>Apparent viscosity at 50s⁻¹ (Pa • s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>4.06 ± 0.43^a</td>
<td>0.33 ± 0.01^a</td>
<td>0.99 ± 0.01</td>
<td>0.30 ± 0.02^a</td>
</tr>
<tr>
<td>CD24</td>
<td>4.76 ± 1.59^a</td>
<td>0.39 ± 0.06^a</td>
<td>0.98 ± 0.00</td>
<td>0.40 ± 0.05^b</td>
</tr>
<tr>
<td>CD32</td>
<td>4.83 ± 0.23^a</td>
<td>0.40 ± 0.23^a</td>
<td>0.98 ± 0.00</td>
<td>0.46 ± 0.01^b</td>
</tr>
<tr>
<td>CD40</td>
<td>6.41 ± 0.34^a</td>
<td>0.37 ± 0.00^a</td>
<td>0.98 ± 0.00</td>
<td>0.56 ± 0.01^c</td>
</tr>
<tr>
<td>CD48</td>
<td>9.47 ± 1.20^b</td>
<td>0.34 ± 0.02^a</td>
<td>0.97 ± 0.01</td>
<td>0.73 ± 0.05^d</td>
</tr>
<tr>
<td>GS40</td>
<td>6.55 ± 0.75^a</td>
<td>0.33 ± 0.04^a</td>
<td>0.99 ± 0.01</td>
<td>0.46 ± 0.02^b</td>
</tr>
<tr>
<td>GS48</td>
<td>9.35 ± 1.42^b</td>
<td>0.28 ± 0.02^a</td>
<td>0.98 ± 0.01</td>
<td>0.55 ± 0.04^c</td>
</tr>
</tbody>
</table>

Foot notes:
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
### 3.3.4 Final drinking yogurt formulation selection

According to the results above, the 50% yogurt formulation was considered as the final formulation of drinking yogurt. The 70% yogurt formulation had potential to be stirred yogurt formulation. Calculated total solid content, total dietary fiber, insoluble dietary fiber, soluble dietary fiber of drinking yogurt are shown in Table 3.9.

**Table 3.9:** Calculated total solid content and calculated dietary fiber content of drinking yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total dietary fiber (g)</th>
<th>Soluble dietary fiber (g)</th>
<th>Insoluble dietary fiber (g)</th>
<th>Total solid content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12.3</td>
</tr>
<tr>
<td>CD24</td>
<td>2.52</td>
<td>0.60</td>
<td>1.92</td>
<td>13.8</td>
</tr>
<tr>
<td>CD32</td>
<td>3.35</td>
<td>0.79</td>
<td>2.56</td>
<td>14.4</td>
</tr>
<tr>
<td>CD40</td>
<td>4.19</td>
<td>1.00</td>
<td>3.20</td>
<td>14.9</td>
</tr>
<tr>
<td>CD48</td>
<td>5.03</td>
<td>1.20</td>
<td>3.84</td>
<td>15.4</td>
</tr>
<tr>
<td>GS40</td>
<td>2.15</td>
<td>0.78</td>
<td>1.37</td>
<td>14.0</td>
</tr>
<tr>
<td>GS48</td>
<td>2.58</td>
<td>0.94</td>
<td>1.65</td>
<td>14.4</td>
</tr>
</tbody>
</table>

### 3.3.6 Drinking yogurt manufacture parameters

The pH, titratable acidity, WHC, and serum separation of drinking yogurt are shown in Table 3.10 and Figure 3.3. The pH value and titratable acidity (TA) of drinking yogurt fortified with different amounts of CDAP (0, 2.4%, 3.2%, 4.0%, 4.8%) showed no significant difference. With an increase in GSAP, the pH value of drinking yogurt did not change. However, the pH value of drinking yogurt fortified with CDAP was significantly higher than the drinking yogurt fortified with the same amount of GSAP. The TA of drinking yogurt increased with the increase in GSAP and were significantly higher than the drinking yogurt fortified with the same amount of CDAP.

The water holding capacity (WHC) of drinking yogurt was significantly different with the increase of CDAP (0, 2.4%, 3.2%, 4.0%). However, there is no significant difference between the WHC of CD40 and CD48. There was no significant difference in the WHC of drinking yogurt
when there was an increase of GSAP (4.0%, 4.8%). Both CDAP and GSAP increased the WHC of drinking yogurt when fortified with a higher amount. However, compared with the same amount of GSAP, CDAP had a strong water holding capacity.

The syneresis of drinking yogurt had significantly decreased after fortifying GSAP and CDAP compared with control. Both GS40 and GS48 had the lowest serum separation, but they had no significant difference between them. While an increase in CDAP, caused the serum separation of drinking yogurt to significantly decrease but would significantly increase if fortified with over 4.0% CDAP. CD32 had the lowest serum separation among all drinking yogurt fortified with CDAP. Both CDAP and GSAP had positive effects on preventing syneresis of drinking yogurt, but GSAP had stronger effects on avoiding syneresis.

Table 3.10: pH, titratable acidity, water holding capacity and serum separation of drinking yogurt (means ± SD)

<table>
<thead>
<tr>
<th>Sample</th>
<th>pH</th>
<th>Titratable acidity</th>
<th>WHC (%)</th>
<th>Serum separation (mL/10 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(% lactic acid/ g yogurt white weight)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>4.74 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.88 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.42 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.01 ± 0.12&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD24</td>
<td>4.80 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.88 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.42 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.47 ± 0.12&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD32</td>
<td>4.80 ± 0.05&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.88 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.47 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.37 ± 0.06&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD40</td>
<td>4.81 ± 0.06&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.90 ± 0.01&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.55 ± 0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.40 ± 0.00&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD48</td>
<td>4.83 ± 0.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.92 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.58 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.60 ± 0.00&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>GS40</td>
<td>4.59 ± 0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.14 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.44 ± 0.00&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.17 ± 0.06&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
<tr>
<td>GS48</td>
<td>4.55 ± 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.28 ± 0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.46 ± 0.01&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.13 ± 0.06&lt;sup&gt;e&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Foot notes:
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
- Means within a column followed by different superscript letters means significant different (P < 0.05)
Figure 3.3: Effects of dried apple peel powders on pH, titratable acidity, water holding capacity and serum separation of drinking yogurt (means ± SD)

3.3.7 Color of drinking yogurt

Table 3.11: Color parameters of drinking yogurt (means ± SD)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Color²</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>±</td>
<td>±</td>
<td></td>
</tr>
<tr>
<td>C0</td>
<td>79.21</td>
<td>± 0.79a</td>
<td>-2.05 ± 0.06a</td>
<td>2.39 ± 0.42a</td>
</tr>
<tr>
<td>CD24</td>
<td>68.87</td>
<td>± 0.35b</td>
<td>4.15 ± 0.36b</td>
<td>20.05 ± 0.28b</td>
</tr>
<tr>
<td>CD32</td>
<td>66.56</td>
<td>± 0.37c</td>
<td>5.25 ± 0.18c</td>
<td>21.45 ± 0.24c</td>
</tr>
<tr>
<td>CD40</td>
<td>64.87</td>
<td>± 0.33c</td>
<td>5.99 ± 0.07d</td>
<td>22.61 ± 0.14d</td>
</tr>
<tr>
<td>CD48</td>
<td>63.99</td>
<td>± 0.22d</td>
<td>6.54 ± 0.12c</td>
<td>22.79 ± 0.12d</td>
</tr>
<tr>
<td>GS40</td>
<td>74.02</td>
<td>± 0.19e</td>
<td>-1.81 ± 0.02a</td>
<td>27.92 ± 0.28e</td>
</tr>
<tr>
<td>GS48</td>
<td>72.92</td>
<td>± 0.18c</td>
<td>-1.67 ± 0.05a</td>
<td>29.17 ± 0.05f</td>
</tr>
</tbody>
</table>

Foot notes:
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
- Means within a column followed by different superscript letters means significant different (P < 0.05)
- L* = lightness; a* = redness (+) and blueness (-); b* = yellowness
The color parameters are shown in Table 3.11 and Figure 3.4. The color parameters of dried apple peel powder enriched drinking yogurt were significantly different (P<0.05) from the control sample C0. L* value was used to estimate the yogurt whiteness. The incorporation of CDAP decreased the L* value of drinking yogurt, which means the yogurt became darker with the increase of CDAP. Increasing 0.8% (2 g) of CDAP, the L* value decreased around 2 units. However, L* value had no significant difference between CD32 and CD40. The L* values of CD40 and GS48 had no significant difference and were significantly lower than the control sample 0, but the L* values of G40 and G48 were significantly 9-10 units higher than the drinking yogurt fortified with the same amount of CDAP. CDAP had a darkened effect on drinking yogurt while GSAP had no darkening effect on the drinking yogurt. In spite of increasing CDAP, a* value had significantly increased to around 0.7 units by increasing 0.8% CDAP. However, the a* value of G40 and G48 had no significant difference with the control sample. In other words, CDAP had a redness effect on drinking yogurt, but GSAP had no greenness effect compared to the control sample. The b* value of the control sample had significant different from drinking yogurt fortified with CDAP and GSAP. With 0.8% CDAP increasing, the b* value had increased around 1.2 to 1.4 units, but there is no significant difference between CD40 and CD48. Increasing GSAP to 0.8%,
the b* had increased to around 1.2 units. Also, the b* values of GS40 and GS48 were significantly higher than those of CD40 and CD48. Both CDAP and GSAP had a yellow effect on the drinking yogurt, but GSAP had a more yellow effect.

### 3.3.8 Viscoelastic properties of drinking yogurt

#### 3.3.8.1 Strain amplitude sweep

The changing of G’ and G” with an increased strain has shown in Figure 3.5. Four regions are shown in the figure for each sample. The linear viscoelastic region is the first region. Followed by a monotonic decrease in values of both G’ and G” (region 2). The cross point is region 3. After the cross point, G’ had a similar monotonic decrease in modulus values while the loss modulus G” had a small increasing trend and then had decreased. The LVR region showed the structure of samples were undisturbed at low deformation G’ and G” were constant. As soon as the modulus started to decrease, the structure of sample was disturbed. The critical strain and limited storage modulus of the LVR are summarized in Table 3.12. The critical strain had no significant difference among all sample regarding LVR.

For the G’ value at LRV, only GS48 had a significant difference from control, and the G’ value of GS48 was higher than other samples. Comparing samples fortified with CDAP, CD24, and CD48, the G’ showed a significant difference. No significant difference was observed between GS40 and GS48. Also, no significant difference in G’ value of LVR was noted between samples with the same amount GSAP and CDAP.
Figure 3.5: Representative plot of storage modulus $G'$ & $G''$ loss modulus versus shear strain of drinkable yogurt containing different dried apple peel powder concentration at 4 ℃.
Table 3.12: Average of parameters obtained by strain sweep (0.1-1000% strain at 1 Hz, 4 °C) of drinking yogurt fortified with different concentration dried apple peel powder

<table>
<thead>
<tr>
<th>Sample</th>
<th>Strain @ LVR (%)</th>
<th>G’ LVR (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>0.35 ± 0.08a</td>
<td>26.83 ± 0.41ab</td>
</tr>
<tr>
<td>CD24</td>
<td>0.35 ± 0.08a</td>
<td>20.28 ± 4.03a</td>
</tr>
<tr>
<td>CD32</td>
<td>0.25 ± 0.00a</td>
<td>27.81 ± 5.13abc</td>
</tr>
<tr>
<td>CD40</td>
<td>0.25 ± 0.00a</td>
<td>29.88 ± 8.03abc</td>
</tr>
<tr>
<td>CD48</td>
<td>0.22 ± 0.05a</td>
<td>41.45 ± 6.18bc</td>
</tr>
<tr>
<td>GS40</td>
<td>0.17 ± 0.00a</td>
<td>33.43 ± 2.83abc</td>
</tr>
<tr>
<td>GS48</td>
<td>0.27 ± 0.12a</td>
<td>48.54 ± 6.21c</td>
</tr>
</tbody>
</table>

Foot notes:
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
- LVR: linear viscoelastic region
- G’: storage modulus
- Means within a column followed by different superscript letters means significant different (P ≤ 0.05)

Figure 3.6: Example of representative plot of storage modulus G’ & G” versus shear stress of drinkable yogurt at 4 °C.

3.3.8.2 Stress amplitude sweep

The plot of G’ and G” versus shear stress for the control sample (CD32) shown in Figure 3.6. From this figure, the maximum shear stress value of the LVR was regarded as the yield point, and the shear stress value at the cross point was regarded as the flow point. The same plot was conducted on all the samples.
The summary of yield point and flow point data is shown in Table 3.13 and Figure 3.7. Compared to the control sample, only the yield point of GS48 was significant different while other samples had no significant difference from the control sample. CD24, CD32, CD40, CD48 had no significant difference in yield point. GS40 and GS48 also had no significant difference in yield point. However, the yield point of CD40 was significantly higher than the one of the GS40 while the yield point of CD48 had no significant difference from GS48. Moreover, GS48 had the highest yield point and flow point observed from Figure 3.7. The flow point of GS48 was significantly higher than those of other samples. Drinking yogurt fortified with CDAP had no significant different flow point, and the samples fortified with GSAP had no significant difference in flow point. No significant difference of the flow point between CD40 and GS40 was noted, as well as that of GS48 and CD48.

**Table 3.13: Yield point and flow point of drinking yogurt generated from stress sweep (Mean ± SD)**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yield point $\tau_y$ (Pa)</th>
<th>Flow point $\tau_f$ (Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>0.08 ± 0.01$^a$</td>
<td>2.54 ± 0.18$^a$</td>
</tr>
<tr>
<td>CD24</td>
<td>0.07 ± 0.02$^{ab}$</td>
<td>1.73 ± 0.82$^a$</td>
</tr>
<tr>
<td>CD32</td>
<td>0.09 ± 0.01$^{ab}$</td>
<td>1.87 ± 0.46$^a$</td>
</tr>
<tr>
<td>CD40</td>
<td>0.08 ± 0.03$^{ab}$</td>
<td>1.48 ± 0.49$^a$</td>
</tr>
<tr>
<td>CD48</td>
<td>0.12 ± 0.01$^{abc}$</td>
<td>2.23 ± 0.24$^{ab}$</td>
</tr>
<tr>
<td>GS40</td>
<td>0.12 ± 0.02$^{bc}$</td>
<td>2.65 ± 0.02$^{ab}$</td>
</tr>
<tr>
<td>GS48</td>
<td>0.15 ± 0.02$^c$</td>
<td>3.07 ± 0.14$^b$</td>
</tr>
</tbody>
</table>

**Footnotes:**
- C0: control; CD24: fortified with 2.4% CDAP; CD32: fortified with 3.2% CDAP; CD40: fortified with 4.0% CDAP; CD48: fortified with 4.8% CDAP; GS40: fortified with 4.0% GSAP; GS48: fortified with 4.8% GSAP
- Yield point: the maximum shear stress value in the liner G’ range
- Flow point: the shear stress value at the G’ & G” cross point
- Means within a column followed by different superscript letters means significant different (P < 0.05)
Figure 3.7: Yield point and flow point of drinking yogurt generated from stress sweep (Mean ± SD)

3.4 Discussion

3.4.1 Dried apple peel powder

3.4.1.1 Composite compounds

GSAP had a lower water activity compared to CDAP. Lower water activity could inhibit the growth of microorganisms and extend the shelf life of food ingredients (Henríquez et al., 2010). Figuerola et al. (2005) reported that the particle size of powdered ingredient ranging from 460 μm to 600 μm exhibited a high-water retention capacity and fat absorption capacity. In our study, the particle size of CDAP (790 μm) was higher than 600 μm, while that of the GSAP (170 μm) had a much smaller particle size under 460 μm. This might lead to higher water retention capacity in CDAP. Conflicting result was reported by Raghavendra et al. in 2006, where they found coconut residue with larger particle size (>500 μm) had low water retention ability. Moreover, Sendra et al. (2010) studied the effects of different particle sizes and dosages of orange by-product powders on stirred yogurt structure. They found that the large particle size and a high dose of fiber could increase the viscosity of the stirred yogurt. However, Garcia-pérez et al. (2005) indicated that both gross orange fiber (0.701 mm to 0.991 mm), and thin orange fiber (0.417 mm to 0.701 mm) had
no significant effect on pH, syneresis of set yogurt when adding 0%, 0.6%, 0.8%, and 1%. Based on previous studies, the larger CDAP particles (0.790 mm) was assumed to have a positive effect on drinking yogurt structure, water holding capacity and viscosity when compared to the small GSAP particles (0.170 mm), but both GSAP and CDAP might affect the pH and syneresis of drinking yogurt.

The color of CDAP and GSAP were also different. The color of GSAP was greener, yellower and lighter, while CDAP had more redness compared to GSAP. Drogoudi et al. (2007) used the principal component analysis and correlation analysis on seven apple cultivars and found that a darker, redder and bluer apple peel contained higher nutrient content, including phenolic compounds. However, our study showed conflicting results suggesting that green GSAP contained 5.46 mg GAE/g more total phenolic content than red CDAP. This conflicting result might be due to the different drying methods of GSAP and CDAP. Wolfe et al. (2003) mentioned the air-dried and freeze-dried processes reduce the loss of total phenolic in apple peels compared to oven dried. GSAP was dried by freeze-dried method while CDAP was dried by oven, which makes GSAP contain higher total phenolic content. Also, this difference could also be due to the different total phenolic extraction methods, different growing conditions, harvest times, and the complexity of compounds in apple peels (Henriquez et al., 2010).

CDAP contained much more total dietary fiber compared to GSAP. It had been observed that the total dietary fiber content of “Ida red” and “Northern Spy” apple skin powders were 43.3% and 38.6% respectively (Rupasinghe et al., 2008). Also, Henriquez et al. (2010) observed the total dietary fiber of fresh and not-grounded dried Granny Smith apple peel to be 47.8% and 39.7% respectively. In our study, CDAP contained 41.93% total dietary fiber. However, GSAP had a lower total dietary fiber (21.53%) compared to previous study, which might be due to the grinding
process. Raghavendra et al. (2006) has reported that the grinding operation destroys the honeycomb physical structure of fiber matrix. In our study, the GSAP went through the grinding process, which disrupted some dietary fiber matrix and might lead to lower dietary fiber content compared to previous study. Additionally, the proportion of soluble and insoluble dietary fiber is crucial for the food ingredient. The appropriate soluble-insoluble ratio for a food ingredient is 0.5 (Figuerola et al., 2005; McKee, & Latner, 2000; Rupasinghe et al., 2008). The soluble-insoluble dietary fiber ratios of GSAP and CDAP were 0.57 and 0.31 respectively. Compared to CDAP, GSAP was more suitable for use as a dietary fiber enriched food ingredient with a well-balanced soluble and insoluble dietary fiber ratio. CDAP contains more insoluble dietary fiber.

3.4.1.2 Functional properties

Water retention capacity (WRC) indicates the amount of water that dried apple peel powder could absorb under specific temperature conditions, soaking time, and centrifugation parameters (Raghavendra et al., 2006). Previous studies showed that high WRC of dried powdered ingredients represented better functional ability in avoiding syneresis of yogurt, which extends formulated products shelf-life (Elleuch et al., 2011). Also, ingredients with a high WRC could refine the viscosity and structure of formulated products (Elleuch et al., 2011; Sendra et al., 2010). The WRC of CDAP was 3.84 g water/g dry weight at room temperature, which is higher than that of GSAP (2.82 g water/g dry weight). As mentioned before, the appropriate larger particle sized powder might have a higher WRC. This might be a reason that CDAP had a higher WRC compared to GSAP. Also, the CDAP (32 g/100 g dry weight) contains much higher insoluble dietary fiber than the one of GSAP (13.73 g/100 g dry weight), which also might give CDAP its higher WRC.

Oil holding capacity (OHC) was the amount of oil that a sample can absorb under specific temperature conditions, soaking time, and centrifugation parameters (Elleuch et al., 2011). OHC
was determined by surface attributes, particle size, overall density, thickness, and hydrophobic nature/structure of particles (Figuerola et al., 2005). CDAP with larger particle size (790 μm) contains 18.27% more insoluble dietary fiber per gram compared to GSAP, and it is supposed to have higher OHC. However, the OHC of CDAP (1.18 g oil/g dry weight) was lower than that of GSAP (1.52 g oil/g dry weight), which was conflicting to the theory of particle size. Henriquez et al. (2013) also had shown that the OHC of dried apple peel varied depending on the drying conditions. The dried apple peel produced by 110 °C-140 °C oven drying had a higher OHC than the one manufactured from freeze drying. However, CDAP produced by oven drying had lower OHC than the freeze-dried GSAP. The reason of difference OHC between CDAP and GSAP still need to be further studied.

Therefore, both GSAP and CDAP can be applied within the food industry as functional dietary fiber enriched ingredients. GSAP contains a well-balanced ratio of soluble-insoluble dietary fiber, high total phenolic content, high sugar. CDAP has good water retention capacity due to its higher insoluble dietary fiber content.
3.4.2 Manufacture parameters of fortified drinking yogurt

GSAP had significantly decreased the pH value and increased the titratable acidity of fortified drinking yogurt, because the pH value of GSAP (3.92) was lower than that of CDAP (5.12). The water holding capacity of drinking yogurt was significantly decreased when fortified with over 3.2% CDAP and 4.8% GSAP. As we discussed before, the water retention capacity of CDAP was 1 g water/g dry weight higher than that of GSAP; this led to the lower water retention capacity of GSAP fortified drinking yogurt. Figuerola et al. (2005) had reported that the different water retention capacity of apple pomace was related to the insoluble dietary fiber content. In our study, CDAP (32%) contained twice as much insoluble dietary fiber compared to GSAP (13.72%). The higher water retention ability of CDAP (3.84 g water/g dry weight) could be associated to the higher amount of insoluble dietary fiber, which causes higher water holding capacity in CDAP fortified drinking yogurt compared to the control and GSAP fortified drinking yogurt. The larger particle size of CDAP (790 μm) might also be the reason behind the higher water retention ability of CDAP fortified drinking yogurt as we mentioned before.

Both GSAP and CDAP significantly decreased the serum separation (syneresis) after 16 days storage, which is expected, because GSAP and CDAP showed good water retention capacity. Conflicting results were found between water holding capacity and syneresis of fortified drinking yogurt in our study. GSAP fortified yogurt had a lower water holding capacity but a lower syneresis value. This could be due to CDAP having higher insoluble dietary fiber content compared to GSAP (e.g. CD40: 3.20 g; GS40: 1.37 g). The higher insoluble dietary fiber content can absorb enough water during storage and start to float and disrupt the structure of drinking yogurt, which can lead to greater serum release and cause higher syneresis rate after 16 days storage. Also, the phenolic content of dried apple peel powder could have a positive effect on
reducing syneresis of drinking yogurt. The number of polyphenols and the polyphenol binding sites of protein molecules could make new cages and inhibit the serum separation from the gel structure (Dönmez et al., 2017). In our study, GSAP (18.00 mg GAE/ g) contained more total phenolic content than the one of CDAP (12.54 mg GAE/ g), which could make GSAP have a better ability to reduce the syneresis of drinking yogurt. However, the syneresis was increased when fortified with over 3.2% CDAP; this was a similar trend in green tea powder fortified drinking yogurt that reported by Dönmez et al. (2017). This phenomenon could be due to the higher amount of insoluble dietary fiber disrupting the homogeneous structure of stirred yogurt and making the solid-liquid stratification occur as mentioned before (Sendra et al., 2010). Hence, 3.2% CDAP is the best fortified amount to obtain the lowest syneresis of CDAP fortified drinking yogurt.

3.4.3 Rheological properties of drinking Yogurt

3.4.3.1 Apparent viscosity and flow behavior

Dried apple peel powder enriched drinking yogurt showed Non-Newtonian and shear thinning (thixotropic) behavior. Dried apple peel powder has increased the apparent viscosity (50 s⁻¹) of drinking yogurt. Staffolo et al. (2004) reported that apple fiber was a significant factor in increasing apparent viscosity of yogurt. Additionally, with the same usage of GSAP and CDAP, the apparent viscosity of CD40 and GS40 had increased to 0.26 (Pa • s) and 0.16 (Pa • s) individually compared to C0. This might be due to the fact that the total dietary fiber content of CD40 (4.19 g) is higher than GS40 (2.15 g) (Table 2.9). Additionally, GS48 showed a higher pseudoplasticity compared to the other samples because the flow behavior index of GS48 (n=0.28) was significantly lower than that of other samples; this would also indicate that GS48 had poor viscosity (Table 3.8). This might be due to high amount insoluble small dietary fiber particles of GSAP. Also, the flow behavior index of CD40 (n=0.37) and CD48 (n=0.34) was lower than the
one of CD32 (n=0.40). These results indicate that the apparent viscosity of drinking yogurt was increased with CDAP, but with higher dose of CDAP, viscosity was increased such that a lower resistance was required in order to achieve proper flow. This suggests that with over 3.2 % CDAP, the gel structure of drinking yogurt started to weaken due to the increase in insoluble dietary fiber content. The consistency coefficient of GS48 (9.47) and CD48 (9.35) had a significantly higher value than other samples and indicates an increased consistency at 4.8% dried apple peel powder. (Table 3.8). Sakin-Yilmazer et al. (2014) had reported similar results before, when 5%, 10%, and 20% candied chestnut was added to stirred yogurt. Their results showed an increase of fiber in the yogurt, a larger degree of shear thinning (higher consistency index) and less resistance to flow (lower flow behavior index). Also, Sanz et al. (2008) showed that the addition of fiber increased the threshold force and the consistency index of yogurt. Therefore, the flow behavior parameters demonstrated that the addition of dried apple peel powder could increase the apparent viscosity and could improve the consistency of reconstituted drinking yogurt within 3.2% CDAP and 4.0% GSAP.

3.4.3.2 Viscoelastic properties

The Storage modulus (G’) was higher than the loss modulus (G”’) in the linear viscoelastic region (LVR) for all samples (Figure 3.5). Drinking yogurt fortified with dried apple peel powder exhibited elastic characteristics in the LVR. The average G’ in the LVR indicated the rigidity (stiffness) of the food material at a resting period. The G’ value is related to the numbers of bonds between casein particles in set yogurt (Sun-Waterhouse et al., 2012). In this study, the drinking yogurt fortified with dried apple peel powder was characterized as a weak structural material since the G’ values were low. The stiffness (G’) of the drinking yogurt was enhanced when fortified
with 4.8% dried apple peel powder, which might bring bad texture mouth feeling for consumers (Table 3.12).

In the first non-linear viscoelastic region, both G’ and G’’ had decreased with an increase in shear strain, and drinking yogurt showing a strain thinning behavior. After the first deformation range (region 2) and cross point (region 3), all the samples became an irreversible fluid since G’ was higher than G’’ displayed on a linear trend. Moreover, the G’’ value of dried apple peel powder had a small increase after the cross point, which indicates that dried apple peel powder fortified yogurt had good liquid properties when it starts to flow, which makes it easy to swallow by consumers.

In the stress sweep, all the yield point values were close to zero. No significant difference in yield point between control and CDAP fortified drinking yogurt was observed, while GS48 (0.15 Pa) had significantly higher yield point compared to others. GS48 also exhibited a significantly higher flow point compared to other samples, which indicates that GS48 required more force to flow. Therefore, drinking yogurt fortified with 4.8% GSAP had a stiffness structure compared to the other samples, which indicates that GSAP had more thickening properties compared to CDAP with the same amount usage. However, the total dietary fiber (2.58 g), soluble dietary fiber (0.94 g) and insoluble dietary fiber (1.65 g) of GS48 were not significantly higher compared to other samples (Table 3.9). Insoluble dietary fiber particles can integrate more with the casein gel to improve the strength of the structure (Raghavendra et al., 2006). Soluble dietary fiber includes pectin substances, gums, mucilage, and some hemicelluloses (Dhigra, Michael, Rajput & Patil, 2012), which could strengthen the gel structure. CD40 (1.00 g) contains similar soluble dietary fiber content level to GS48 (0.94 g), but CD40 contains 2 times more insoluble dietary fiber compared to GS48 (Table 3.9). Moreover, the particle size of CDAP is 4.65 times bigger than that
of GSAP. Therefore, GS48 contained a higher total number of insoluble dietary fiber particles due to the smaller particle size compared to CD40. GS48 contains higher number of insoluble dietary fiber particles that integrate more with casein gel, which leads to more stiffness of GS48. Espírito-Santo et al. (2013) also reported casein gels were enhanced structurally when fortified with date fiber because the casein gel would overlay the fiber. Therefore, increasing the number of insoluble small dietary fiber particles might help to strengthen the gel structure of drinking yogurt. However, the strong gel structure of drinking yogurt might not have accepted by consumers due to requiring higher force to make drinking yogurt to flow.

3.5 Conclusion

To conclude the results of this chapter, the proximate components of GSAP and CDAP were different in terms of total dietary fiber, and total sugar, total phenolic content. CDAP contains significantly more insoluble dietary fiber (32.00%) compared to GSAP (13.73%) while the soluble dietary fiber content was similar in both samples. On the contrary, the total sugar content of GSAP was two times that of CDAP. In terms of differences in color GSAP showed more greenness while CDAP showed more redness. Based on these results, we assumed both GSAP and CDAP can be dietary fiber enriched ingredients in food manufacture to increase the viscosity of drinking yogurt. Both dried apple peel powder could have modified the color of food products, which might impact the consumer acceptance of drinking yogurt. Both GSAP and CDAP might reduce the syneresis problem in drinking yogurt during storage due to the water retention capacity. Also, the particle size of CDAP is 0.79 mm, which is 4.65 times larger than the one of GSAP, which might lead to different effects of CDAP and GSAP on the rheological and sensory properties of drinking yogurt.

GSAP fortified yogurt exhibited lower pH value and titratable acidity (TA) while CDAP had no significant effect on the pH or TA value of drinking yogurt. Both CDAP and GSAP can decreased
syneresis in the drinking yogurt while syneresis had increased with increasing concentration of CDAP over 3.2%. The water holding capacity of drinking yogurt increased when fortified with more than 3.2% or 4.8% of CDAP and GSAP respectively. Drinking yogurt fortified with CDAP showed redness while the drinking yogurt fortified with GSAP had a greening effect on the drinking yogurt.

Fortified drinking yogurt was characterized as a shear thinning fluid with low apparent viscosity. The viscosity of drinking yogurts increased with an increase in CDAP addition while the flow behavior index had decreased with over 3.2% CDAP and 4.0% GSAP. GS40 and CD32 exhibited the same apparent viscosity and total solid content (Table 3.8 & Table 3.9). In terms of rheological parameters, the loss modulus (G’) and storage modulus (G’’) increased with an increase in dried apple peel powder. However, the critical strain at the linear viscoelastic region (LVR) had no significant impact between all drinking yogurts. Both GSAP and CDAP had a significant effect on the G’ value of drinking yogurt in LVR when added in concentrations higher than 4.0%, but only GSAP increased the yield and flow point of the drinking yogurt. With higher amount of dried apple peel powder particles, the stiffness of drinking yogurt was increased. Adding higher than 4.0% GSAP, the fortified drinking yogurt might not be accepted by consumers due to the stiffness structure.

Therefore, dried apple peel powder can be added to drinking yogurt to produce a dietary fiber enriched yogurt product. Both GSAP and CDAP increased the viscosity and decreased syneresis in the drinking yogurt, as well as modified the rheological properties and color of the drinking yogurt with the appropriate concentration of dried apple peel powders (3.2% CDAP & 4.0% GSAP). In particular, high number of particles increased the stiffness of drinking yogurt. Moreover, when fortified with more than 4.0% GSAP, the structure of drinking yogurt continued
to improve. These results suggest that GSAP fortified drinking yogurt could be produced at a higher dilution compared to regular drinking yogurt to decrease costs.
CHAPTER 4: EFFECTS OF DRIED APPLE PEEL POWDERS ON SENSORY PROPERTIES OF DRINKING YOGURT

4.1 Introduction

Drinking yogurt is regarded as portable yogurt and easy to consume for consumers. Drinking yogurt is made by diluting from yogurt. Fruit syrup or purees are usually added to adjust the flavor in the yogurt production, it is preferred by consumers compared to plain drinking yogurt (Tamime & Robinson, 2007). Drinking yogurt is also considered to be a carrier of additional nutrient compounds such as dietary fiber (Cliff et al., 2013). With the increased research into the health benefits of dietary fiber, consumers have consciously started to increase their intake of dietary fiber (Hashim, Khalil, & Afifi, 2009). One source of added dietary fiber that has been studied is dried apple peel which also adds natural apple flavor and color. To develop dietary fiber enriched yogurt, several researchers have studied the effects of dietary fiber on sensory properties of yogurt (Espírito-Santo et al., 2013; Hashim et al., 2009; Issar, Sharma, & Gupta, 2017; Marchiani et al., 2016; Sendra et al., 2008, Staffolo et al., 2004).

Yogurt fortified with apple fiber (1.3%) has been found to have increased brown color that negatively impacted consumer acceptance (Staffolo et al., 2004). Consumers rejected apple pomace fortified yogurt when over 5.0% of apple pomace as added to yogurt due to its effect on color, flavor, and consistency (Issar, Sharma, & Gupta, 2017). Similarly, stirred yogurt fortified with grape skin powder was not accepted by consumers due to an increase in sourness, lower sweetness, and a grainy texture (Marchiani et al., 2016). These studies show that adding dietary fiber to yogurt changes the sensory properties of yogurt in appearance, flavor, and texture, leading
to a decrease in consumer liking. To understand the effects of dried apple peel powder on sensory properties of drinking yogurt, a consumer acceptance test was conducted.

4.2 Material and Methods

4.2.1 Materials

Skim milk, skim milk powder, sugar, water, Thermophilic YoFlex® culture (Chr. Hansen), Granny Smith dried apple peel powder, commercial dried apple peel powder, natural pectin, crackers, napkin, FN-18353 apple flavor (Essences & Fragrances), high methoxyl (HM) pectin and low methoxyl (LM) pectin (Modernist Pantry), FN-18353 apple flavor (Essences & Fragrances) 30 ml plastic containers with lids.

Table 4.1: Formulation of 3 samples for sensory evaluation

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yogurt (%)</th>
<th>HM Pectin (%)</th>
<th>Sugar (%)</th>
<th>GSAP/DDAP (%)</th>
<th>Water (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>50</td>
<td>0.30</td>
<td>9</td>
<td>0</td>
<td>40.70</td>
</tr>
<tr>
<td>CD32</td>
<td>50</td>
<td>0.26</td>
<td>8.2</td>
<td>3.2</td>
<td>38.74</td>
</tr>
<tr>
<td>GS40</td>
<td>50</td>
<td>0.25</td>
<td>7.1</td>
<td>4.0</td>
<td>39.45</td>
</tr>
</tbody>
</table>

4.2.2 Sample preparation

Drinking yogurt samples were prepared following the manufacturing procedure. Drinking yogurt containing 50% yogurt was chosen as the final formulation. Three samples were chosen from the final formulation for the sensory evaluation: 1) control drinking yogurt without dried apple peel powders, and 0.3% FN-18353 apple flavor (Essences & Fragrances) was added to give it the same apple flavor level 2). drinking yogurt fortified with 4.0% dried Granny Smith apple peel powder (GSAP) containing 2.20 g total dietary fiber, and 3) drinking yogurt fortified with 3.2% commercial dried apple peel powder (CDAP) containing 3.36 g total dietary fiber. The formulation
can be seen in Table 4.1. The concentration of dried apple peel powder in the fortified drinking yogurt samples were determined by matching the apparent viscosity (0.46 ± 0.02 Pa • s & 0.46 ± 0.012 Pa • s for C32 and G40 respectively).

Samples were prepared one day before each sensory test in the food formulation lab in Food Science building at the University of Guelph. Drinking yogurt was packed in 30 ml plastic containers with lids and stored in the refrigerator at 4 °C for 12 h.

4.2.3 Panelist Recruitment

Ethics approval was received from the University of Guelph Research Ethics Board (REB#17-05-031) before panelist recruitment. Panelists were recruited by e-mail to students and faculties of the University of Guelph and by posters placed around the campus. A total of 103 adults aged 18 to 50 years old were recruited from the University of Guelph. This age range was chosen as it is typical of yogurt consumers. Participants were compensated with a $10 University of Guelph hospitality gift card after completing the test.

4.2.4 Procedure

Before beginning the tasting, participants were asked to complete a screening questionnaire (Appendix A) to verify there are no allergies/sensitivities to the ingredients of drinking yogurt. A consent form (Appendix B) was also signed before the test. Participants were also able to indicate that they would like a copy of the results once they were analyzed.

During the test, the panelists were seated in individual tasting booths and were asked to answer a questionnaire using a computer software program (Compusense® Five; Compusense Inc, Guelph) while tasting the three samples. All samples were labeled with a 3-digit blinding code for tasting and were served at 4 °C. Water and crackers were offered to the panelists to cleanse their palate.
between tasting each sample. For each panelist, the order of tasting of the samples was randomized to reduce the effects of sample serving order.

Before the start of the test, consumers were provided with instructions on how to complete the test. They were also provided with instruction sheets that they could bring into the test booth. Then, the participants received a questionnaire (Appendix C) for each sample, which contained consumer liking acceptance questions and “Just About Right” questions. A 9-point hedonic scale was used to evaluate consumer liking from 1 to 9 (1-Dislike Extremely, 5-Neither like nor dislike, 9-Like Extremely). Participants were asked to rate liking of the product texture, flavor, and appearance, as well as overall liking for each sample. Following the hedonic questions, participants evaluated the thickness, sweetness, sourness, apple flavor and colour of the drinking yogurts using 5-point “Just About Right” scales (1 = Too Little, 3 = Just About Right, 5 = Too Much) (Li, Hayes & Ziegler, 2014, Lawless & Heymann, 2010; Meilgaard, Civille & Carr, 2007). Finally, participants were also asked whether they would like to purchase the product or not at the end of question list. In total, the test took approximately 20 mins.

4.2.5 Statistic analysis

Analysis of Variance (ANOVA) at a 95% confidence in interval was used for the consumer liking data set to determine whether there were any significant differences in liking of appearance, texture, flavor and overall liking among the three samples (Control, GS40, & CD32). Tukey’s Honestly Significant Difference (HSD) posthoc test as used to determine where a significant difference existed between samples.

For “Just About Right”, plotting the data as a simple histogram to examine the frequencies across the scale. Secondly, a binomial probability (against an expected value of 0.5) test was conducted to show if the data skewed higher or lower than the middle point for each sample.
Finally, a penalty analysis was conducted to determine which attributes are impacting liking of the samples.

All data was analyzed using XLSTAT Version 2014.4.09 (Addinsoft 1995-2014 ©).

4.3 Results

4.3.1 Consumer liking test

The results of the ANOVA for liking of appearance, texture, flavor, and overall liking among different drinking yogurt shown in (Appendix D). The result showed significant differences (p < 0.05) of appearance (F = 40.26, p < 0.0001), texture (F = 21.61, p < 0.0001), flavor (F = 32.05, p < 0.0001), and overall liking (F = 30.47, p < 0.0001) among the three samples

Table 4.2: Summary of mean liking score of appearance, texture, flavor and overall liking of all drinking yogurt samples (HSD)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Appearance (Mean ± SD)</th>
<th>Texture (Mean ± SD)</th>
<th>Flavor (Mean ± SD)</th>
<th>Overall liking (Mean ± SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>6.7 ± 1.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.3 ± 1.8&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.9 ± 1.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.7 ± 1.7&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>GS40</td>
<td>5.2 ± 1.90&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.9 ± 1.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.5 ± 2.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.6 ± 1.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD32</td>
<td>4.4 ± 1.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.7 ± 2.0&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.8 ± 2.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.7 ± 1.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Foot notes:
1: n= 103
2: Data input on 9-point hedonic scale where 1 = dislike extremely; 5 = neither like or dislike, and 9 = like extremely.
3: Means in a column with the same letter are not significantly different (p≥0.05)
4: Difference superscripts within the same column are significantly different by Turkey Honestly Significant Difference (HSD) test (p < 0.05).

Table 4.3: Dietary fiber content and the viscosity value of drinking yogurt

<table>
<thead>
<tr>
<th>Sample</th>
<th>Total dietary fiber (g)</th>
<th>Insoluble dietary fiber (g)</th>
<th>Soluble dietary fiber (g)</th>
<th>Total solid content (%)</th>
<th>Apparent viscosity at 50s&lt;sup&gt;-1&lt;/sup&gt; (Pa • s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>0.39 ± 0.02&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>CD32</td>
<td>3.35</td>
<td>2.56</td>
<td>0.79</td>
<td>14</td>
<td>0.46 ± 0.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>GS40</td>
<td>2.15</td>
<td>1.37</td>
<td>0.78</td>
<td>14</td>
<td>0.46 ± 0.02&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Footnotes:
-Different letters mean a significant difference (P<0.05)
-Control: control; CD32: fortified with 3.2% CDAP; GS40: fortified with 4.0% GSAP;
-Controlled ramped shear rate sweep test. The shear rate ($\dot{\gamma}$) was increased from 0.13 to 300 s$^{-1}$

The mean scores of liking are shown in Table 4.2, which were analyzed by Tukey HSD posthoc test. The mean scores for the liking of appearance, flavor as well as overall liking among the three samples were all significantly different. However, no significant difference was observed in the liking of texture of GS40 and the control, while the liking of the texture of CD32 sample was significantly lower. The Control sample was liked the most for appearance, texture, flavor, and overall liking. The liking of appearance, flavor, and overall liking for C32 was lowest among three drinking yogurts, and the mean scores were lower than the central point “Neither like nor Dislike.”

4.3.2 Just-About-Right

The frequency of responses for the Just-About-Right test are shown in Figure 4.1, Figure 4.2, and Figure 4.3. The control sample had the highest frequencies of Just-about-Right point for color (75%), apple flavor (60%), sourness (70%) and sweetness (65%) compared with GSAP and CDAP. However, the thickness of control sample had lowest frequencies of Just About Right rating for thickness (37%). Compared to the other samples, the control as considered to be too thin (61%), while CD32 was found to be too dark (67%).
The mean score results of the JAR scale and the results of one sample \( t \)-test of product attributes mean compared to the center point’s value (3) on the JAR scale is shown in Table 4.4. For the mean score of color for all three samples showed a significant difference from the optimal colour. The color of control was significantly below the JAR point, which means the color of the control is lighter than ideal for consumers while GS40 and CD32 were perceived to be darker than ideal.
Similarly, the sweetness of all 3 samples showed significant differences from the JAR point. The control sample was perceived to be sweeter than the JAR point while GS40 and CD32 were less sweet than the JAR point.

For the thickness of drinking yogurt, consumers perceived the control sample to be thinner than the optimal level. However, the average rating for thickness of GS40 and CD40 were not significantly different from the just about right value, which means the thickness of both dried apple peel fortified drinking yogurts were in the ideal level for the consumer. Moreover, the apple flavor and the sourness of GS40 were not significantly different to the JAR point. Interestingly, the control sample showed a low apple flavor, and CD32 showed strong apple flavor. Both control sample and CD32 had lower sourness than the optimal level.

Penalty analysis was also conducted with the Just-About-Right data set and overall liking 9-point scale dataset to obtain an understanding of how each attribute affected consumer liking (Lawless and Heymann, 2010; Narayanan, Chinnasamy & Clark, 2014). Penalty analysis aggregates consumers into three groups based on their response to the JAR: “too little”, “too much” and Just-About-Right. Then, the mean overall liking for each of the consumer groups was calculated. The mean drop in liking scores was calculated for the “too little” and “too much” groups by subtracting the mean overall liking score from that of the consumers in the JAR category. Mean drops are then plotted on the y-axis and the percentage of the total consumer participants for each category on the x-axis. When a point shows a large mean drop and a high percent of consumer liking, it is suggested that the attribute be modified in the appropriate direction (Lawless and Heymann, 2010). If an attribute causes a mean drop of 1 or more and impacts 20%-25% or more of consumer respondents, these attributes were included in a critical corner of the plot and should be modified in the product.

Table 4.4: Summary of mean score of colour, thickness, apple flavor, sourness and sweetness (one-sample t-test)
<table>
<thead>
<tr>
<th>Attributes</th>
<th>Sample</th>
<th>Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>Control</td>
<td>2.72 ± 0.63*</td>
</tr>
<tr>
<td></td>
<td>GS40</td>
<td>3.28 ± 0.92*</td>
</tr>
<tr>
<td></td>
<td>CD32</td>
<td>3.80 ± 0.86*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>Control</td>
<td>2.15 ± 0.86*</td>
</tr>
<tr>
<td></td>
<td>GS40</td>
<td>3.16 ± 0.84</td>
</tr>
<tr>
<td></td>
<td>CD32</td>
<td>3.06 ± 1.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple flavor</td>
<td>Control</td>
<td>2.69 ± 0.80*</td>
</tr>
<tr>
<td></td>
<td>GS40</td>
<td>2.79 ± 1.08</td>
</tr>
<tr>
<td></td>
<td>CD32</td>
<td>3.80 ± 1.07*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soursness</td>
<td>Control</td>
<td>2.60 ± 0.72*</td>
</tr>
<tr>
<td></td>
<td>GS40</td>
<td>3.13 ± 0.86</td>
</tr>
<tr>
<td></td>
<td>CD32</td>
<td>2.68 ± 0.81*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweetness</td>
<td>Control</td>
<td>3.24 ± 0.72*</td>
</tr>
<tr>
<td></td>
<td>GS40</td>
<td>2.82 ± 0.79*</td>
</tr>
<tr>
<td></td>
<td>CD32</td>
<td>2.79 ± 0.82*</td>
</tr>
</tbody>
</table>

Foot notes:

a: n= 103
b: Data input on 5-point Just-About-Right scale where 1 = too little; 3 =Just-About-Right, and 5 = too much.
*: P < 0.05 (significant mean below or above Just-About-Right point based on one-sample t-test).

Consumer panel percentage of three sample for each level (1 - “too little”, 3 - “just about right”, and 5 - “too much”) are shown in Figure 4.4, Figure 4.5, and Figure 4.6. For the control, only 36% consumers thought the thickness was Just-About-Right, which is much lower than other attributes. However, 61% consumers indicated the thickness was “too thin”. For the GS40, 38% consumers indicated the apple flavor was just right, which was the lowest percentage among all attributes. However, 39% consumers thought the apple flavor was “too low”. For the CD32, only 25% consumers thought the color intensity was just about right, and 67% consumers indicated the color of CD32 was too dark. Moreover, 43% consumers stated the apple flavor of CD32 was too low, which is higher than the percentage of consumers that indicate the apple flavor of CD32 was just about right.
Figure 4.4: Consumer panel percentage of the JAR 1, 3, 5 level for control

Figure 4.5: Consumer panel percentage the JAR 1, 3, 5 level for GS40
The consumer overall liking mean score of control sample and percentage of “too much”, “too little” and JAR group are shown in Table 4.5 and Appendix E. For the control sample, the JAR penalty values of all attributes were significantly different, which indicated all of the attributes affected decreasing mean consumer liking. However, the JAR penalty of colour, sourness, and sweetness mean drop values were over 1, so the colour, sourness and sweetness were the primary attributes that impacted consumer acceptance for the control sample. Moreover, 24.3% consumers indicated the colour of control was too light, which decreased consumer liking by 1.09 on the 9-point hedonic scale. 28.2% consumers indicated the sweetness of control was too high. However, the mean drop value of “too much” sweetness was less than 1, indicating this is not a critical attribute.

The penalty results of GS40 are shown in Table 4.6 and Appendix E, penalty values of all attributes of GS40 significantly impacted mean consumer liking, and all the penalties were over 1. These results showed all the attributes contributed to a decrease consumer liking. Also, mean drops of “too much” colour (1.10), “too much” thickness (1.56), “too little” sweetness (1.46), and both “too much” (1.99) and “too little” apple flavor (1.52) had a significant impact on consumer liking.
38.8% of consumers indicated the colour of GS40 was too dark. 28.2% consumers indicated GS40 was too thick, which made them dislike the overall product by a mean drop of 1.56 on the 9-point hedonic scale. Also, 29.1% consumers indicated the sweetness of GS40 was not high enough. Interestingly, apple flavor had both two-direction impacts on the consumer acceptance, although more (38.8%) consumers thought the apple flavor of GS40 was not enough (23.30%) rather than too much. Narayanan et al. (2014) had reported when both the “too little” and “too much” groups had effects on consumer liking and included over 20% participants, then only the group including the higher percentage of participants should be considered as a critical attribute. Therefore, 38.8% consumers indicated the apple flavor of GS40 was not enough, which had decreased the overall liking of GS40.

The penalty analysis results of CD32 is shown in Table 4.7 and Appendix E. The penalties values of colour (1.52), thickness (1.21), apple flavor (1.77), and sourness (1.15) experienced penalties and had a significant effect on consumer liking with penalty scores over 1. “too much” colour, “too much” thickness, “too little” apple flavor, and “too little” sourness had a significant effect on the mean of overall liking for CD32.

Moreover, 67% of consumers indicated the colour of CD32 was too dark, which corresponded to a decrease in the consumer liking. The colour of CD32 was the main attribute to impact consumer liking because the mean of overall liking had decreased 1.61 (mean drop) on the 9-point hedonic scale due to the dark colour. Additionally, 29.1% of consumers showed CD32 was too thick, causing the overall liking to decrease by 1.6 on the 9-point hedonic scale. 42.7% of consumers thought the apple flavor of CD32 was too weak, causing a decreasing in the average liking score of 1.57. For the sourness, 35.9% of consumers indicated it to be too weak. However, the mean drop value of “too little” sourness was 0.93 indicating that the “too little” sourness was
not one of the main attributes that negatively impacted the consumer liking of CD32. At the end, 22%, 44%, and 69% consumers stated would purchase CD32, GS40, and control sample.
### Table 4.5: Data for penalty analysis of control sample and mean drop

<table>
<thead>
<tr>
<th></th>
<th>Mean (overall liking)</th>
<th>Mean Drop</th>
<th>Consumer $^6%$</th>
<th>Penalty $^5$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Colour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too light</td>
<td>5.9</td>
<td>1.1$^3,^a$</td>
<td>24.3</td>
<td></td>
</tr>
<tr>
<td>Just-About-Right</td>
<td>7.0</td>
<td></td>
<td>72.8</td>
<td>1.2$^a$</td>
</tr>
<tr>
<td>Too dark</td>
<td>5.0</td>
<td>2.0$^4$</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td><strong>Thickness</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too thin</td>
<td>6.4</td>
<td>0.8$^3,^a$</td>
<td>61.2</td>
<td></td>
</tr>
<tr>
<td>Just-About-Right</td>
<td>7.1</td>
<td></td>
<td>35.9</td>
<td>0.8$^a$</td>
</tr>
<tr>
<td>Too thick</td>
<td>6.3</td>
<td>0.8$^4$</td>
<td>2.9</td>
<td></td>
</tr>
<tr>
<td><strong>Apple flavor</strong></td>
<td></td>
<td></td>
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<td>Too weak</td>
<td>6.2</td>
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<td>58.3</td>
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<td>5.7</td>
<td>1.4$^4$</td>
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<tr>
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<td></td>
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<td></td>
</tr>
<tr>
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<td>1.0$^3,^a$</td>
<td>31.1</td>
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<td></td>
<td></td>
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**Foot notes:**

1: n= 103
2: Data input on 9-point hedonic scale where 1 = dislike extremely; 5 = neither like or dislike, and 9 = dislike extremely.
3: Mean drop shows how many points of liking you lose for having a product "too much" or "too little" for a consumer: mean drop “too little” = Mean JAR – Mean “too little” group
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5: Penalty shows how many points of liking you lose for not being as expected by the consumer. It is a weighted difference between the means (Mean of Liking for JAR - Mean of Liking for the two other levels taken together)
6: how many % consumer corresponding to each level
$^a$: means significant difference
Table 4.6: Data for penalty analysis of GS40 and mean drop

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<td>4</td>
<td>5</td>
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<td>Mean (overall liking)</td>
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<tr>
<td>Too light</td>
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<td>15.5</td>
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<td>1.3 a</td>
</tr>
<tr>
<td>Too dark</td>
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<td>38.8</td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>Mean Drop</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Too thin</td>
<td>4.8</td>
<td>1.4</td>
<td>17.5</td>
<td></td>
</tr>
<tr>
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<td>5.4</td>
<td></td>
<td>1.5 a</td>
</tr>
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<td>28.2</td>
<td></td>
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<tr>
<td>Apple flavor</td>
<td>Mean Drop</td>
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<td></td>
<td></td>
</tr>
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<td>1.5</td>
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<td>Too strong</td>
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<tr>
<td>Sourness</td>
<td>Mean Drop</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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</tr>
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<td>1.4 a</td>
</tr>
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<td>5.2</td>
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<tr>
<td>Sweetness</td>
<td>Mean Drop</td>
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<td></td>
</tr>
<tr>
<td>Too weak</td>
<td>4.7</td>
<td>1.5</td>
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</tr>
<tr>
<td>Just-About-Right</td>
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<td>1.3 a</td>
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<tr>
<td>Too strong</td>
<td>5.3</td>
<td>0.9</td>
<td>15.5</td>
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6: how many % consumer corresponding to each level
a: means significant difference b: means no significant difference
Table 4.7: Data for penalty analysis of CD32 and mean drop

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<tr>
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<td>(overall liking)</td>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>Too light</td>
<td>5.0</td>
<td>0.8³</td>
<td>7.8</td>
</tr>
<tr>
<td></td>
<td>Just-About-Right</td>
<td>5.8</td>
<td>25.2</td>
<td>1.5 a</td>
</tr>
<tr>
<td></td>
<td>Too dark</td>
<td>4.2</td>
<td>1.64, a</td>
<td>67.0</td>
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<td>4.5</td>
<td>0.8³, b</td>
<td>23.3</td>
</tr>
<tr>
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<td>5.3</td>
<td>47.6</td>
<td>1.2 a</td>
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<td></td>
<td>Too thick</td>
<td>3.7</td>
<td>1.64, a</td>
<td>29.1</td>
</tr>
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<td>1.6³, a</td>
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<tr>
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<td>1.8 a</td>
</tr>
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<td></td>
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<td>3.6</td>
<td>2.24</td>
<td>19.4</td>
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<td>0.9³, a</td>
<td>35.9</td>
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<td></td>
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<td>54.4</td>
<td>1.2 a</td>
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<td></td>
<td>Too strong</td>
<td>3.2</td>
<td>2.04</td>
<td>9.7</td>
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<td>Too weak</td>
<td>4.4</td>
<td>0.6³, b</td>
<td>32.0</td>
</tr>
<tr>
<td></td>
<td>Just-About-Right</td>
<td>4.95</td>
<td>54.4</td>
<td>0.6 b</td>
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<td></td>
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<td>4.21</td>
<td>0.74</td>
<td>13.6</td>
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Foot notes:

1: n= 103
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3: Mean drop shows how many points of liking you lose for having a product “too much” or “too little” for a consumer: mean drop “too little” = Mean JAR – Mean “too little” group
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6: how many % consumer corresponding to each level
a: means significant difference b: means no significant difference
4.4 Discussion

4.4.1 Consumer liking

The consumer liking of texture, flavor, appearance, and overall liking was significantly different among the three samples (CD32, GS40 & Control). The results showed that incorporating dried apple peel powder affects the appearance, texture, flavor, and overall liking of drinking yogurt. This is similar to previous studies showing that incorporating plant-based phytonutrients, and bioactive compounds has negative effects on consumer liking of foods, such as yogurt, and yogurt drinks (Allgeyer et al., 2010; Gonzalez, et al., 2011; Hashim, Khalil, & Afifi, 2009; Marchiani et al., 2016;).

Comparing the three samples with each other, the control sample was the most appreciated by consumers and got the highest liking scores for appearance, texture, flavor and overall liking. GS40 has a lower consumer acceptance compared to control sample, which could be due to the control sample has a similar sensory property to commercial products that consumers are used to. The drinking yogurt fortified with commercial dried apple peel powder (CDAP) was the most disliked by consumers, notably in terms of the appearance. Even though both CDAP and GSAP have impacted the appearance of drinking yogurt, only the appearance of CDAP is not accepted by consumers. Hoppert et al. (2013) have reported yogurt fortified with visible fruit dietary fiber decrease consumer acceptance due to an unfamiliar appearance. However, 1.3% bamboo, wheat, and apple fiber had no impact on the consumer acceptability of set yogurt (Staffolo et al., 2004). This is likely due to the low concentration of enriched fiber present in the fortified yogurt.

However, there is no significant difference in the liking of texture between the control and GS40. Additionally, CD32 was fortified with 3.2% CDAP while GS40 was fortified with 4.0% GSAP. Even though GS40 contained more dried apple peel powder, it had a better texture compared to
CD32. This is probably because CD32 (2.56 g) contained more insoluble dietary fiber than GS40 (1.37 g) (Table 4.3). Also, CDAP (790 μm) had larger particle size compared with GSAP (170 μm), which could be the other reason leading to a negative texture of drinking yogurt. Staffolo et al. (2004) used small particle size (less than 32 μm) of bamboo, apple, and wheat fiber into set yogurt, and the consumer liking of texture had not changed with the additional fiber. Tomic et al. (2017) had also studied the effects of insoluble triticale, wheat, and oat dietary fiber on sensory properties of set yogurt. They found that particle size was the main factor impacting the consumer acceptance in terms of the texture of yogurt. The previous study also found that consumers had indicated a sandy texture in set yogurt fortified with fiber particles less than 17.7 μm (Espírito-Santo et al., 2013). In our study, the particle size of GSAP (170 μm) and CDAP (790 μm) is larger than 17.7 μm, which could lead to sandy texture of drinking for consumers. Additionally, not only did the amount and particle size of the fortified fibers impact the texture of drinking yogurt, the shape of the fiber molecules could also have a negative effect on texture. Insoluble fiber particles have sharp edges that can cause a sandy mouth feeling for consumers (Espírito-Santo et al., 2013). In our study, from Table 4.3, GS40 (0.78 g) and CD32 (0.79 g) contain same amount of soluble dietary fiber while the GS40 contains 1.37 g (0.55%) insoluble dietary fiber while CD32 contains 2.56 g (1.02%) insoluble dietary fiber. Hence, the insoluble fiber content is considered the primary factor impacting consumer liking in terms of the texture of drinking yogurt. Even though the particle size of the insoluble dietary fiber is relatively small (17.7 μm), at high concentrations, it can negatively affect consumers preference. This could be due to the insoluble dietary fiber particle shape can bring sandy texture to consumers (Espírito-Santo et al., 2013). In our study, both GSAP (170 μm) and CDAP (μm) could bring sandy mouth feeling to consumers due to particle size.
4.4.2 Just-About-Right

Based on the combination of consumer liking, consumers preferred the drinking yogurt fortified with GSAP rather than the one fortified with CDAP. A penalty test was conducted to determine how much consumer liking decreased based on each of the attributes tested with the JAR scale.

The color of both GS40 (3.28) and CD32 (3.80) were darker than the just right level (3) while the color of the control sample (2.72) was considered too light. This means, that there is an opportunity to apply the right amount of dried apple peel powder to have positive effects on the color of the drinking yogurt. The natural color of the powder because GSAP has a natural green color, while CDAP is naturally red. However, the limitation is that the concentration of dried apple peel powder must change to adjust the color of drinking yogurt, which will change other parameters of drinking yogurt, such as viscosity.

With the same sugar content in the formulation, the sweetness of the control yogurt (3.24) was sweeter than the just right level, but both CD32 (2.82) and GS40 (2.79) were not sweet enough. Previous studies showed that insoluble dietary fiber from cereals could be used to lower the perceived sweetness since the cereal insoluble dietary fiber enriched yogurt was indicated not sweet enough by consumers compared to the control (Hoppert et al., 2013; Tomic et al., 2017). Hence, based on the consumers’ rating of the sweetness of the drinking yogurts, dried apple peel powder, especially CDAP, could have reduced the perceived sweetness of drinking yogurt. The total sugar from dried apple peel powder cannot contribute enough sweet flavor compared to the commercial sugar. This could be a limitation for drinking yogurt development.

Both GS40 and CD32 had an ideal thickness from the just right level while the texture of control sample was indicated not enough by consumers, which was expected. The mechanical apparent viscosity of both CD32 and GS40 was the same at the 50 second⁻¹ shear rate (Table 4.3), and the
same thickness level of GS40 and CD32 was expected and just right in the ideal thickness level of consumers. Hence, 3.2% CDAP and 4.0% GSAP are the appropriate concentration to obtain an ideal thickness level of drinking yogurt. Although the insoluble dietary fiber of GS40 is 1.19 g higher than that of CD32, both GS40 and CD32 still had the same apparent viscosity.

The thickness of the drinking yogurt was related to the texture of the drinking yogurt. However, consumers preferred the control and GS40 texture rather than the CD32 texture despite CD32 and CD40 having the same viscosity and the same thickness intensity level. This conflicting result again proves that consumers did not prefer the texture of CD32 possibly due to the sandy mouth feeling of CDAP, which could be due to the high insoluble dietary fiber content and large particle size of CDAP as previously demonstrated. When the additional fiber particle size is 17.7 μm, it could be felt in set yogurt by consumers because of the sharp edges of insoluble fiber particles (Espírito-Santo et al., 2013). However, in drinking yogurt, large particle size insoluble particles (CDAP: 790 μm) could bring a sandier mouthfeel compared to small particle size (GSAP 170 μm). Larrauri (1999) reported the typical particle size distributions of commercial high dietary fiber ranges from 150 μm to 430 μm. Kimura et al. (2015) also found that the threshold particle size of core granules is 244 μm in order to obtain a rough mouthfeel. Hence, the particle size of CDAP (790 μm) need to be reduced to avoid bring a rough mouthfeel to consumers in drinking yogurt development while the particle size of GSAP (170 μm) is acceptable by consumers. Therefore, even though adding 3.2% CDAP could obtain an ideal thickness level for drinking yogurt, CDAP had effects on the texture of drinking yogurt due to the detectable larger particle size for consumers. However, GSAP is appropriated to using as an additional dietary fiber ingredient to obtain an ideal thickness and an acceptable texture of drinking yogurt.
The apple flavor intensity of GS40 was in the ideal range for consumers. The control showed not enough apple flavor while CD32 showed too strong apple flavor. This indicated that dried apple peel powder improved the flavor of drinking yogurt rather than artificial apple flavor that was used in the control sample. However, the artificial apple flavor concentration using in control sample was decided by the developer when adjust the same apple flavor level to GS40 and CD32. Also, panelists could have different apple flavor preference from the developer. This could be a limitation of the apple flavor Just-About-Right scale in methodology. Hence, dried apple peel powder could be considered as a substitute for artificial apple flavor in subsequent flavored drinking yogurt manufacturing when fortified with appropriated amounts. Adding 4.0% GSAP could bring and ideal apple flavor to consumers while adding 3.2% CDAP brings too much apple flavor.

4.5 Conclusion

Including dried apple peel powder in drinking yogurt had an impact on consumer liking in terms of texture, flavor, appearance, and overall liking. The control sample was liked most by consumers, followed by GSAP fortified drinking yogurt. The commercial dried apple peel powder was least preferred, getting the lowest liking score (<5) in all the attributes. In particular, consumers indicated the texture of GSAP fortified drinking yogurt was the same as the control sample and the thickness of both GS40 and CD32 were indicated in the ideal level by consumers. The low liking of the texture of the CD32 yogurt might be due to the graininess caused by larger particle size and high amount insoluble dietary fiber of CDAP.

The intensity of thickness, apple flavor, and sourness were at the ideal level for GSAP fortified drinking yogurt. The thickness of control was too thin, and the color of CDAP fortified drinking yogurt was too dark, which were expected and had decreased the overall liking of drinking yogurt.
Therefore, dried apple peel powder affected consumer liking of drinking yogurt. GSAP is more appropriate to use as a dietary fiber enriched ingredient compared to CDAP due to small particle size and better soluble-insoluble ratio. Reducing the thickness and colour and increasing the apple flavor of the CDAP fortified yogurt could improve the overall consumer liking while it is not easy to operate with the adjusting the concentration of CDAP in yogurt industry.
CHAPTER 5: CONCLUSION AND FUTURE WORK

The current study was focused on investigating the effect of dried apple peel powder on the rheological and sensory properties of drinking yogurt for developing dietary fiber enriched drinking yogurt. Granny Smith dried apple peel powder (GSAP) and commercial dried apple peel powder (CDAP), which are the by-products from the apple processing industry, were determined as dietary fiber enriching ingredients. The dietary fiber content of GSAP and CDAP was 21.53% and 41.93%. Moreover, GSAP had an appropriate soluble dietary fiber and insoluble dietary fiber ratio (0.57) and was suitable for the production of drinking yogurt compared to CDAP (0.31). It is important to know the impact of dried apple peel powder on the structural and sensory properties of drinking yogurt for functional yogurt industry at an early stage.

GSAP and CDAP have been successfully applied to drinking yogurt manufacture in this study. GSAP had significantly decreased the pH value and increased the titratable acidity of fortified drinking yogurt compared to CDAP. The syneresis of fortified drinking yogurt has decreased due to the total phenolic content and the water retention capacity of dried apple peel powder. However, the syneresis of drinking yogurt has increased when fortified with over 3.2% CDAP due to the high amount of insoluble dietary fiber lead to serum release. The water holding ability of drinking yogurt was increased when fortified with more than 3.2% CDAP or 4.8% of GSAP.

The rheological properties of the fortified drinking yogurt were explored in this study. The flow behavior and apparent viscosity of the yogurt were determined by controlled shear rate sweep test. The results showed drinking yogurt fortified with dried apple peel powder was characterized as shear thinning flow behavior food materials, and the apparent viscosity (50%) increased with dried apple peel powder increasing. The viscoelastic properties of drinking yogurt were determined by
the oscillatory tests, shear strain sweep and shear stress sweep. The fortified drinking yogurt showed elastic characteristics in the linear viscoelastic region of strain sweep, and the flow point was observed from stress sweep. The drinking yogurt fortified with dried apple peel powder was characterized as a weak structural material.

The rheology tests also had evaluated the limited concentrations of dried apple peel powder using in fortified drinking yogurt manufacture. When fortified with 4.0% and 4.8% CDAP or 4.8% GSAP, the apparent viscosity of the drinking yogurts was over the industry requirement ( < 0.5 Pa • s). Also, the fortified drinking yogurt with 4.0% and 4.8% CDAP had weak gel structure due to the increase in insoluble dietary fiber content. The stiffness (G’) and flow point of drinking yogurt were significantly increased by fortifying 4.8% GSAP compared with the control sample due to the high insoluble dietary fiber. This means the structure of this drinking yogurt was relatively strong, which might bring bad texture mouth feeling for consumers and not suitable for drinking yogurt production. Therefore, drinking yogurt fortified with 3.2% CDAP (CD32) and 4.0% GSAP (GS40) were applied to the sensory evaluation.

The sensory evaluation was conducted on three samples, the CD32, GS40 and the control sample without dried apple peel powder. A 9-point scale was used to evaluate the consumer liking in appearance, texture, flavor, and overall liking of drinking yogurt. A 5-point Just-About-Right scale was used to evaluate the intensity of color, thickness, apple flavor, sourness, and sweetness of drinking yogurt. The control sample (6.7/9) was most like by consumers, which might be due to the control sample is similar to the commercial products that consumers are used to consuming. The drinking yogurt fortified with 3.2% CDAP (4.7/9) was the most disliked by consumers, notably regarding the grainy texture due to the insoluble dietary fiber and the larger particle size. The drinking yogurt fortified with 4.0% GSAP (5.6/9) was accepted by consumers in overall liking.
Both CDAP and GSAP had negative effects on the texture of drinking yogurt due to the particle size. Hence, the particle size of CDAP (790 µm) needs to be reduced to avoid bringing a rough mouthfeel to consumers in drinking yogurt development while the particle size of GSAP (170 µm) could be used in drinking yogurt manufacture and accepted by consumers.

Moreover, fortifying 4.0% GSAP could refine the thickness, apple flavor, and sourness intensity level of drinking yogurt to the consumers ideal level. In addition, adding 3.2% CDAP could refine the thickness level of drinking yogurt to the consumers ideal level. However, the artificial apple flavor concentration used in control sample was decided by the developer to adjust the apple flavor of the control sample to the same level as GS40 and CD32. Also, panelists could have different apple flavor preference. This could be a limitation of the apple flavor Just-About-Right scale in methodology. Also, the sweetness of the dried apple peel powder fortified drinking yogurt was not enough, especially for CDAP fortified drinking yogurt. Even though dried apple peel powder contains high total sugar, the total sugar from dried apple peel powder cannot contribute enough sweet flavor compared to commercial sugar. This could be a limitation for drinking yogurt development. Both GSAP and CDAP could improve the color of drinking yogurt, but the color of fortified drinking yogurt was darker than the just right level. In this case, changing the color of fortified yogurt is another limitation in drinking yogurt development.

The future work could be focused on reducing the grainy texture of drinking yogurts fortified with different concentration of dried apple peel powders. Stokes et al. (2013) suggested that texture analysis, sensory perception evaluation, rheology properties measurement are three main key methods to measure the texture of food. Tribology is used to study the oral processing to understand the correlation between food texture and mouthfeel of consumers.
References:


Kalinowska, M., Bielawska, A., Lewandowska-Siwkiewicz, H., Priebe, W., & Lewandowski, W. (2014) Apples: Content of phenolic compounds vs. variety, part of apple and cultivation
model, extraction of phenolic compounds, biological properties. *Plant Physiology and Biochemistry*, 84, 169-188. doi: 10.1016/j.plaphy.2014.09.006


PCM. (2017). Retrieved from:  


Appendix A

Drinking Yogurt Screening Survey Questionnaire

Thank you for your interest in participating in our functional drinking yogurts sensory evaluation tests. To make sure that you meet the inclusion criteria needed for the research, we would like to ask you a few questions.

Are you an adult (more than 18 years old)?

You will be eating samples that contain the following ingredients:
Skim milk, Granny Smith dried apple peel powder, commercial dried apple peel powder, water, sugar, active bacterial cultures (Lactobacillus bulgaricus and Streptococcus thermophilus), fruit pectin.
Do you have any allergies to these ingredients?

Do you have any intolerance or sensitivities yogurt products?

If you are allergic to these ingredients or you have any sensitivities to drinking yogurt products, please do not take part in this study.

Signature of Witness:

________________________________________
Name of Witness (please print)

________________________________________                      _________________
Signature of Witness                      Date
Appendix B

CONSENT TO PARTICIPATE IN RESEARCH

Consumer Acceptance and “Just about right” Testing of Drinking Yogurt

You are asked to participate in a research study conducted by Zening Zhou as part of her master project in the Department of Food Science. Dr. Gisele LaPointe is her advisor, and Dr. Lisa Duizer is her co-advisor. This project is funded by the NSERC/Dairy Farmers of Ontario IRC.

If you have any questions or concerns about the research, please feel free to contact Gisele LaPointe: Faculty member in the Department of Food Science. University of Guelph, glapoint@uoguelph.ca Phone: 519-824-4120 ext 52099.
Lisa Duizer: Faculty member in the Department of Food Science, University of Guelph, lduizer@uoguelph.ca Phone: 519-824-4120 ext 53410.

PURPOSES OF THE STUDY

The purposes of this study are: To find out the consumer acceptance of the functional drinking yogurt fortified with dried apple peel powders.

PROCEDURES

In this study, during tasting session, you will be provided with three samples of drinking yogurt. You have to answer the questionnaire on the computer during tasting the samples.

You will be eating products that contain the following ingredients: skim milk, sugar, water, active yogurt bacterial culture (Lactobacillus bulgaricus and Streptococcus thermophilus), Granny Smith dried apple peel powder, commercial dried apple peel powder, natural fruit pectin.
These products have been made in the formulation lab located in the Food Science building following good manufacturing principles.

Additionally, you will be cleansing your palate with soda crackers and water between different samples.

It is not anticipated that you will suffer any adverse reactions to consuming these products. The quantities served are all smaller than you would eat under normal situations. You do not have to eat the entire sample presented to you. You have to eat enough to make an evaluation. You are free to take the leftovers with you when you go.

In total, this tasting session will take approximately 20 mins. If you would like a copy of the results, we will send you a summary at the completion of the project by email.

You will be compensated with $10 per 20mins for the time you take to be involved with our study.

POTENTIAL RISKS AND DISCOMFORTS

If you do not have any allergies/discomfort with any of the listed ingredients, there are no known risks to being involved with this study other than the risk of choking which occurs whenever food is eaten.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

There is no direct benefit to you for taking part in this research.

CONFIDENTIALITY

Every effort will be made to ensure confidentiality of any identifying information that is obtained about this study. All data which is collected will be stored on a password protected computer.

PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. You may exercise the option of removing your data from the study up until the end of the data collection period. You may also refuse to answer any questions you don’t want to answer and still remain in the study. If you couldn’t finish the test and leave, we couldn’t withdraw your incomplete data.

RIGHTS OF RESEARCH PARTICIPANTS
If you have questions regarding your rights and welfare as a research participant in this study (REB#17-05-031), please contact: Director, Research Ethics; University of Guelph; reb@uoguelph.ca; (519) 824-4120 (ext. 56606)

You do not waive any legal rights by agreeing to take part in this study.

This project has been reviewed by the Research Ethics Board for compliance with federal guidelines for research involving human participants

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I have filled in the screening questionnaire for allergies and I have read the ingredients listing for the products that I will be consuming. I am not allergic or sensitive to any of the listed items.

I have read the information provided for the study “Consumer Acceptance Testing of Drinking Yogurt” as described herein.

My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____________________________________
Name of Participant (please print)

____________________________________
Signature of Participant

____________________________________
Date

Please provide us with your email address if you would like a copy of the results:

Email: ________________________________
Appendix C

Sample #

1. How much do you like the **Appearance** of the drinking yogurt? Check one of the option below.

<table>
<thead>
<tr>
<th>Dislike extremely</th>
<th>Dislike very</th>
<th>Dislike moderately</th>
<th>Dislike slightly</th>
<th>Neither like or dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very</th>
<th>Like Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Please indicate your opinion about the color.

<table>
<thead>
<tr>
<th>Too light</th>
<th>Just right</th>
<th>Too dark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. How much do you like the **Texture** of the drinking yogurt? Check one of the option below.

<table>
<thead>
<tr>
<th>Dislike extremely</th>
<th>Dislike very</th>
<th>Dislike moderately</th>
<th>Dislike slightly</th>
<th>Neither like or dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very</th>
<th>Like Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Please indicate your opinion about the thickness.

<table>
<thead>
<tr>
<th>Too thin</th>
<th>Just right</th>
<th>Too thick</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. How much do you like the **Flavor** of the drinking yogurt? Check one of the option below.
6. Please indicate your opinion about the apple flavor.

<table>
<thead>
<tr>
<th>Option</th>
<th>Dislike extremely</th>
<th>Dislike very much</th>
<th>Dislike moderately</th>
<th>Dislike slightly</th>
<th>Neither like or dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

7. Please indicate your opinion about the sourness.

<table>
<thead>
<tr>
<th>Option</th>
<th>Too low</th>
<th>Just right</th>
<th>Too high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

8. Please indicate your opinion about the sweetness.

<table>
<thead>
<tr>
<th>Option</th>
<th>Too low</th>
<th>Just right</th>
<th>Too high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

9. How much do you like the Overall of the drinking yogurt? Check one of the option below.

<table>
<thead>
<tr>
<th>Option</th>
<th>Dislike extremely</th>
<th>Dislike very much</th>
<th>Dislike moderately</th>
<th>Dislike slightly</th>
<th>Neither like or dislike</th>
<th>Like slightly</th>
<th>Like moderately</th>
<th>Like very much</th>
<th>Like Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

10. Would you like to purchase it in the supermarket?

<table>
<thead>
<tr>
<th>Option</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Appendix D

ANOVA results for consumer liking of appearance, texture, flavor, and overall liking

<table>
<thead>
<tr>
<th>Attributes</th>
<th>DF</th>
<th>Sum of squares</th>
<th>Mean squares</th>
<th>F</th>
<th>Pr &gt;F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>2</td>
<td>271.63</td>
<td>135.82</td>
<td>40.26</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Texture</td>
<td>2</td>
<td>150.12</td>
<td>75.06</td>
<td>21.61</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Flavor</td>
<td>2</td>
<td>236.42</td>
<td>118.26</td>
<td>32.05</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Overall liking</td>
<td>2</td>
<td>202.67</td>
<td>101.33</td>
<td>30.47</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>
Appendix E

Consumer panel percentage & mean drops of the JAR 1, 3, 5 level for control, GS40, CD32