UNIVERSITI PUTRA MALAYSIA

NUTRITIONAL COMPOSITION AND COST BETWEEN GLUTEN-FREE FOOD PRODUCTS AND GLUTEN-CONTAINING FOOD PRODUCTS IN FEDERAL TERRITORY OF KUALA LUMPUR, MALAYSIA

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BY

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ABSTRACT

Recently, the accessibility of gluten-free food products has been expanded broadly by food manufacturers because they can be purchased easily from the stores. However, to date, there is no information available in Malaysia on nutritional composition of gluten free products versus gluten-containing food products. Therefore, the objective of this study was to investigate the nutritional composition (energy, carbohydrate, protein, fat and dietary fibre) based on Nutrition Information Panel and cost per 100g between gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia. The nutritional composition and cost of 106 food products were determined and compared: gluten-free food products (n = 41) with gluten-containing food products (n = 65) available from 4 grocery stores in Federal Territory of Kuala Lumpur, Malaysia were purposively selected. An independent samples t-test was used to determine the differences in nutritional composition and cost between both food products. The findings showed that the energy content was significantly higher especially in the gluten-free brownie mix and spaghetti ($p < 0.05$), and carbohydrate content was higher in gluten-free all-purpose flour and spaghetti ($p < 0.05$) than gluten-containing food products. Low protein content was found in gluten-free bread mix, chocolate cake mix, all-purpose flour, spaghetti and biscuits ($p < 0.05$). Across all gluten-free food products, only lasagne sheet was determined as having a low content of dietary fibre ($p < 0.05$). The cost for the majority of gluten-free food products was significantly higher as compared to gluten-containing food products ($p < 0.05$). In conclusion, this study showed that the gluten-free food products had an overall similar nutritional composition with gluten-containing food products except for protein content and the cost. Excessive consumption of gluten-free food products does not give any beneficial effects toward health but rather show critical health conditions such as overweight and obesity.

ABSTRAK

Baru-baru ini, akses kepada produk makanan yang bebas gluten telah berkembang meluas oleh pengeluar makanan. Walau bagaimanapun, setakat ini, tiada maklumat di Malaysia mengenai komposisi pemakanan produk makanan yang bebas gluten berbanding produk makanan yang mengandungi gluten. Oleh itu, objektif kajian ini adalah untuk mengkaji komposisi pemakanan (tenaga, karbohidrat, protein, lemak dan serat) berdasarkan Panel Maklumat Pemakanan dan kos setiap 100g di antara produk makanan yang bebas gluten dan produk yang mengandungi gluten di Wilayah Persekutuan Kuala Lumpur, Malaysia telah dipilih secara bertujuan. Komposisi pemakanan dan kos untuk 106 produk makanan telah ditentukan dan dibandingkan: produk makanan yang bebas gluten (n = 41) dengan produk makanan yang mengandungi gluten (n = 65) yang terdapat di 4 kedai di Wilayah Persekutuan Kuala Lumpur, Malaysia. Satu sampel ujian-t bebas telah digunakan untuk menentukan perbezaan dalam komposisi pemakanan dan kos antara kedua-dua produk makanan. Dapatan kajian menunjukkan bahawa kandungan tenaga adalah jauh lebih tinggi terutamanya dalam produk makanan yang bebas gluten iaitu *brownies* dan spageti ($p < 0.05$), dan kandungan karbohidrat adalah lebih tinggi pada tepung serba guna dan spageti yang bebas daripada gluten ($p < 0.05$). Kandungan protein rendah ditemui dalam produk makanan yang bebas gluten iaitu tepung roti, *brownies*, tepung kek coklat, tepung serba guna, spageti dan biskut ($p < 0.05$). Di antara semua produk makanan yang bebas gluten, hanya kepingan lasagna yang mempunyai kandungan yang rendah serat ($p < 0.05$). Kos bagi kebanyakan produk makanan yang bebas gluten adalah jauh lebih tinggi berbanding dengan produk makanan yang mengandungi gluten ($p < 0.05$). Kesimpulannya, kajian ini menunjukkan bahawa produk makanan yang bebas gluten mempunyai komposisi pemakanan yang lebih kurang sama dengan produk makanan yang mengandungi gluten kecuali kandungan protein dan kosnya. Penggunaan produk makanan yang bebas gluten yang berlebihan tidak memberi kelebihan yang baik terhadap kesihatan tetapi sebaliknya boleh menyebabkan keadaan kesihatan yang kritikal seperti lebih berat badan dan obesiti.

CHAPTER 1

INTRODUCTION

1.0 Background

Gluten is interpreted as the main storage protein fragment for wheat-based products (Saturni, Ferretti, & Bacchetti, 2010). It is also commonly used in contributing the viscosity and elasticity properties especially in baked products such as dough (Biesiekierski, 2017). Gluten is often used as the preservative, flavor enhancer, coloring and have the power in retaining the moisture of the dough (Biesiekierski, 2017). Apart from that, gluten also acts as water absorber that can cause cohesion and can stabilize the heat which it can highly imply the sticking and binding forces (Wieser, 2007). When flour and water are mixed and synthesized together, the network of proteins such as glutenin and gliadin that are present in wheat is shaped (Shewry et al., 2002). The well-known gluten-containing products were usually found in wheat, barley and rye (do Nascimento et al., 2014; Matos & Rosell, 2011).

Recently, the demand for gluten-free bakery products has increased worldwide due to the rising awareness of celiac disease that has impacted people (Stantiall & Serventi, 2018). Wheat-flour based baked goods such as bread mix, cake mix, and other food products including pasta products and biscuits are common foods that contain gluten (Missbach et al., 2015). The term "gluten-free" is a nutrient

content claim as defined in the Code of Federal Regulations and can be declared on any food product that contains less than 20 ppm (parts per million) of the gluten in foods; whether the food is naturally free of gluten or has been specially processed to remove gluten from its formulation (Saturni et al., 2010).

The gluten-free diet has been popular since the number of gluten-free food products is growing from day to day as many healthy populations who do not have celiac disease were engaged with a gluten-free diet (Rosell & Matos, 2015). Due to the demand of gluten-free food products, the food manufacturer has been experiencing a steeply increasing trend in sales of gluten-free products from USD 4639.13 Million and USD 7594.43 Million in 2015 and 2020 and predicted to grow with a compound annual growth rate (CAGR) between 9.0% and 10.2% during 2016-2022 (Report Summary Gluten-Free Products Market Analysis by Product, 2018).

Gluten-free diet is embellished further due to the elevated number of celiac patients in the world (Stanley, Hammed, & Asiyanbi, 2018). The results of meta-analysis based on 96 studies from year 1991 to 2016 reported that the prevalence of celiac disease in South America was 4% followed by 0.8% in Europe and Oceania, 0.6% in Asia and 0.5% in Africa and North America (Celiac Disease Foundation, 2018). Celiac disease is been described as an immune disorder that occurs in the small intestinal mucosa in the vulnerable people from their genes due to the reaction of gluten resulted from inflammation in the intestinal mucosa of the small intestine (Watkins & Zawahir, 2017). Many people in the world have an immense interest in gluten-free diet and believe that gluten-free food products could contribute to their overall health in various ways, ranging from assisting in weight loss and other diseases such as irritable bowel syndrome, inflammation (Lebwohl, Ludvigsson, & Green, 2015).

1.2 Problem statement

Changes of dietary behavior are known to be associated with the emerging and rapid phase of urbanization and industrialization in the world (Noraida et al., 2018). The development of diverse types of chronic non-communicable diseases is known to be related to these changes especially in dietary changes among the population. The changes in the food purchasing among the population has appeared as serious issues due to the demand for healthy foods that has increased and influenced the trends in food consumption pattern among Malaysian (Sheng et al., 2008).

The Report Summary Gluten-Free Products Market Analysis by Product (2018) , reported that many people nowadays were likely to adopt a healthy lifestyle by eating any foods that considered as healthy foods due to a high prevalence of nutrient-related diseases such as obesity. Over the years, the prevalence of obesity was growing rapidly and becoming a serious public health concern (Teo et al., 2014). The demand of gluten-free food products and organic foods has been increased extensively by people in order to reduce the risk overweight and obesity (Report Summary Gluten-Free Products Market Analysis by Product, 2018).

A recent study by Newberry et al., (2017) reported the gluten-free food products turned out as a trend to people because it has been consumed uncontrollably by those healthy people which they do not even need any medical priorities. In addition, people also believed that gluten-free food products were beneficial for them because they thought that gluten-free food products were more nutritious, can help in reducing the body weight and safe for their health (Stanley, Hammed & Asiyanbi, 2018).

However, the gluten-free diet may create several risks due to imbalances of nutrients that can lead to crucial implications for the overall health such as an increase in weight and also associated with heart problems (Kulai & Rashid, 2014). This issue needs to be focused because in 2016, it was approximately 1.9 billion adults were overweight and 650 million were obese worldwide (World Health Organization, 2018). The National Health and Morbidity Survey (NHMS) reported that the prevalence of overweight and obesity among Malaysian adults more than 18 years old had increased rapidly from 16.6% to 30.0% for overweight and 4.5% in 1996 to 17.7% in 2015 for obesity (Lim, 2016).

Gluten-free food products had a low content of protein and dietary fibre but higher in carbohydrate, fat and sugar as these components were used in enormous quantities to balance the texture and imply the binding forces due to the non-existence of gluten in the dough products (Kulai & Rashid, 2014). In addition, gluten-free food products were more costly than gluten-containing food products (Capacci, Leucci, & Mazzocchi, 2018). Therefore, the objective of this study was to investigate the nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel and cost per 100g between gluten-free and gluten-containing food products in selected grocery stores in Federal Territory of Kuala Lumpur, Malaysia.

1.3 Significance of the study

By doing this study, it is able to provide and extend more knowledge about the nutritional composition and cost of gluten-free food products versus gluten-containing food products in Malaysia. According to my knowledge, there is no study done yet on nutritional composition and cost of gluten-free food products versus

gluten-containing food products in Malaysia. But, it is hugely important to find out the comparison of nutritional composition and cost between both food products due to a high demand for gluten-free food products. Therefore, further study needs to be done to provide new knowledge among Malaysian so that they will be more sensible of the current trend of food consumption nowadays.

Moreover, this study will give additional benefits by producing more information among people to ensure that they will accomplish healthy diet requirements for their daily life as well. Besides, this information will be useful for nutritionist and other health care workers to emerge more awareness and guide people that require gluten-free diet for their health requirements which need to be based on necessity only and assist those whom likely to buy gluten-free food products even they are already healthy in reading food labels correctly and making the right choices so that it can reduce the financial burden among the population.

1.4 Objectives

The objectives of this research are as following:

1.4.1 General objective

To investigate the nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel and cost per 100g between gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.

1.4.2 Specific objectives

1. To determine the nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel per 100g between gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.

2. To compare the nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel per 100g between gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.

3. To determine and compare the cost per 100g between gluten-free food products and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.

1.5 Hypotheses

1. There is a significant difference between the nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel per 100g of gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.
2. There is a significant difference between the cost per 100g of gluten-free and gluten-containing food products in Federal Territory of Kuala Lumpur, Malaysia.

CHAPTER 2

LITERATURE REVIEW

2.1 Gluten

2.1.1 Gluten and its properties

Gluten is a complex protein network which is made of glutenin and gliadin (Food and Drug Administration, 2018). It is commonly used in contributing the viscosity and elasticity properties especially in baked products. Based on the National Wheat Foundation (2014), the gluten will help the baked product such as bread to enlarge and keep the shape properly. The perfect shape of dough formation is determined by the right proportions of two proteins that insoluble in water namely glutenin and gliadin in the gluten itself (do Nascimento et al., 2014). A disulphide bond is the bond that was formed between glutenin and gliadin when the water is added (Wieser, 2007). When disulphide bond is formed, it managed to trap gases and increase the elasticity of the structure of the dough (Pellegrini & Agostoni, 2015). The effect of stretching strands of gluten network would make the dough became more fluffy and chewy (Ravinder et al., 2018).

In addition, when the dough is already hydrated, basically, the gliadin will cause the dough to be more viscose and broaden whereas the glutenin are more cohesive and will improve the strength of the dough (Wieser, 2007). Moreover, it is known to be resistance to heat and has the capacity to imply the sticking and binding

forces to the dough (Biesiekierski, 2017). Gluten is also being commonly used as preservative, flavor enhancer as well as food coloring. Besides, gluten also has the power in absorbing the moisture and improving the texture of the dough in the bakery heating process (Lam & Nickerson, 2013).

2.1.2 Celiac disease

Recently, The Food and Drug Administration (2018) claimed that there are approximately 3 million of people in United States with celiac disease. The results of meta-analysis based on 96 studies from year 1991 to 2016 reported that the prevalence of celiac disease in South America was 4% followed by 0.8% in Europe and Oceania, 0.6% in Asia and 0.5% in Africa and North America (Celiac Disease Foundation, 2018). However, in Malaysia, the prevalence of celiac disease among healthy adults was 1.25% respectively (Yap et al., 2015). According to Watkins and Zawahir (2017), celiac disease is one of the diseases that resulted from irregular activity of the body's immune system towards the ingestion of gluten in the diet. This is because gliadin and glutenin were wrongly identified by the immune system of celiac disease patients as foreign substances, thus destroyed them respectively (Niland & Cash, 2018).

From the ingestion of the gluten into the gastrointestinal system of the body, the immune system will be responded towards the reactions of toxicity in the gliadin and caused the inflammation of the mucosal of the intestinal system followed by the damage of the villous and gut permeability which can further bloated the stomach by the accumulation of gas and fluid and thus affected the changes of the bowel pattern (Verma et al., 2017). According to Makharia (2014), the inflammation in the mucosal of small intestine had been triggered by the interaction between antibodies and

glutamine followed with enzyme transglutaminase. Diarrhea and chronic fatigue were the examples of remarkable symptoms of celiac disease due to nutritional deficiencies (Ravinder et al., 2018).

Similar study from Italy also stated that by having these symptoms, all of the nutrients from the foods that have been eaten will not be absorbed well which can lead to nutritional deficiencies (Vici, Belli, Biondi, & Polzonetti, 2016). There was no other choice because the treatment for celiac disease can only be relied on long-lasting gluten-free diet throughout life (Stantiall & Serventi, 2018). A consistent practice following to a gluten-free diet might be beneficial for digestive system function to those celiac disease patients (Gaillard, 2016).

2.1.3 Gluten-free foods

Based on Code of Federal Regulations by Food and Drug Administration (2018), the term "gluten-free" means that there is less than 20 ppm (parts per million) of the gluten in foods (Saturni et al., 2010). Gluten-free diet had been firstly introduced among celiac disease patients only (Mulder et al., 2013). The same authors also claimed that, by having this diet, it can minimize all of the symptoms that caused the inflammation in the intestinal wall thus the body will be able to absorb all nutrients from the foods effectively.

The availability of gluten-free bakery products has increased dramatically among people in the last five years (Stantiall & Serventi, 2018). However, the gluten-free diet can strengthen the tendency of increasing in weight and getting heart disease due to imbalances of diet that may pose significant implications for the overall health (Kulai & Rashid, 2014). To be more specific, there was one report by Gaesser and Angadi (2012), indicated that body weight of patients with celiac disease whom

currently following a gluten-free diet increased attributed by the absorption of nutrients and the healing process of intestinal wall lining. Next, the similar report also claimed that gluten-free diet worsen the Body Mass Index (BMI) status of celiac disease patients especially among those overweight and obese patients due to its high content of carbohydrate and fat (Gaesser & Angadi, 2012). The number of gluten-free food products was growing rapidly and becoming a serious public health concern in Asian market because of prices, low awareness about the food products and high cases of undiagnosed people (Masih, 2018).

2.2 Nutritional composition of gluten-free foods

There was a major concern in nutritional composition of gluten-free foods. Gluten-free food products also was known to have low content of protein, fibre, vitamin and mineral but high in carbohydrate, fat and sugar as these three components are used in enormous quantities to balance the texture and imply binding forces due to the non-existence of gluten in the products (Kulai & Rashid, 2014). The major nutritional composition which are carbohydrate, protein, fat, and dietary fibre are the focus of this study since these three are the basic essential nutrients that can provide energy and fuel for the normal human body's function.

2.2.1 Energy

The Report of a Joint FAO/WHO/UNU Expert Consultation (2004) reported that energy requirement is referred as the daily requirements, which is derived from the macronutrients such as carbohydrate, protein and fat for the metabolic and physiological functions of humans as well as to balance the energy expenditure. The demand of gluten-free food products had increased promptly because people perceive that gluten-free food products could provide fuel for energy and enhance health status

(Newberry et al., 2017). The energy content of gluten-free food products including biscuits, pasta products, rusks and breads were different than gluten-containing food products which gluten-free food products generally had higher energy content (Cornicelli et al., 2018).

Besides, gluten-free brown bread also showed that it contained higher energy content than gluten-containing brown bread (Allen & Orfila, 2018). Another study also claimed that gluten-free food products had higher energy content which resulted from more sugar and fat that are needed to improve the texture as well as the flavor (Cross, 2013).

2.2.2 Carbohydrate

Carbohydrate is the main source of energy for human to live because it provides the greatest range of total energy intake which is 50% to 65% of total energy intake (National Coordinating Committee for Food and Nutrition, 2017). According to the Carbohydrates and Health Report, the classification of carbohydrate was based on their own chemistry which are sugars monosaccharides, disaccharides, polyols, oligosaccharides and polysaccharides (Scientific Advisory Committee on Nutrition, 2015). Foods that contained high sources of carbohydrates are mainly cereals, wheat, fruits, and vegetables. This shows that carbohydrate is very important as human really need these staple foods to acquire energy which 1g of carbohydrate provides 4 kcal of energy.

The quality of bakery product such as bread is highly controlled by the starch as this element could not be replaced by other ingredients (Litwinek et al., (2016). Based on the study of nutrient composition of gluten-free breads and pasta products in Canada, it showed that gluten-free breads and pasta products were found to contain

high carbohydrate content compared to gluten-containing breads and gluten-containing pasta products (Kulai & Rashid, 2014). This statement also been supported by Missbach et al., (2015) that reported the same result which all gluten-free food products such as biscuits, spaghetti, lasagne sheet, flours and other bakery products had higher carbohydrate content than the gluten-containing food products.

2.2.3 Protein

Protein is very important in human life as it plays a major role in human growth which 1g of protein provides 4 kcal of energy for body. Furthermore, there are two types of amino acids which are essential amino acids and non-essential amino acids. Technically, human body cannot produce 9 out of 20 essential amino acids which need to be consumed from foods itself. These amino acids were also crucial as precursors for many coenzymes, hormones, nucleic acid and other molecules in the body (Wu, 2016). Almost 10-20% of the daily energy was from protein (National Coordinating Committee for Food and Nutrition, 2017).

Furthermore, there was significant result by one study in Brazil which had recently found out that all of the gluten-free bread, pasta products, biscuits and cake mix tested had lower protein contents than gluten-containing food products (do Nascimento et al., 2014). The other previous study by Kulai and Rashid (2014), also claimed that gluten-free food products such as bread and pasta were classsified as having low protein content compared to gluten-containing bread and pasta product. The study reported by Fry, Madden and Fallaize (2018) also declared the same finding which the protein content in gluten-free food products was lower compared to gluten-containing food products.

2.2.4 Fat

Fat is another nutrient that is essential in human diet for physiological function and body development. Meanwhile, fat provide higher energy with 9.0 kcal/g to the body compared with 4.0 kcal/g from carbohydrate and protein. Excess fat that is been stored in adipose tissue can be utilized for energy when there was limited foods and glucose production in order for human to survive (National Coordinating Committee for Food and Nutrition, 2017).

High amount of fat and sugar are used as these elements were the ones that contributed for an improvement of appearance and better quality of gluten-free bread and pasta due to non-existence of gluten (Kulai & Rashid, 2014). A study by Litwinek et al., (2016), stated that the formulation of gluten-free food products were advance and most of the food manufacturers used food additives such as emulsifiers and organic acids to maintain the structure and shelf life of dough products that could lead to escalation of fat content in gluten-free food products. Besides, there was also a study reported that the amount of fat content could be twice than the usual amount due to calories replacement for carbohydrate content. The increased amount of fat content in gluten-free bread and pasta was essential for the dough quality as well as its palatability.

2.2.5 Dietary fibre

The American Association of Cereal Chemists (AACC) in 2001 reported that dietary fibre is described as a plant-derived food and carbohydrate form that cannot be digested by enzymes in the large intestine in human bodies but could soften the tools as well as reduce the hardness of passing stools (Camire et al., 2001). Dietary fibre can be divided by two types namely soluble fibre and insoluble fibre which can

provide many benefits as it could reduce the risks of getting constipation, colorectal cancer, and cardiovascular disease (Hager, 2012). Moreover, dietary fibre is always being ignored by general populations especially among celiac disease patients where they did not consume foods that contain dietary fibre in adequate amounts and lower than recommended prescriptions (Mijatov et al., 2016).

This issue could be supported by Grehn et al., (2001) which reported that gluten-free bread consumption among celiac disease patients was significantly lower (28%) in dietary fibre than gluten-containing bread (38%). A study by Kulai and Rashid (2014) in assessing nutritional adequacy of packaged gluten-free food products also concluded that gluten-free pasta had lower dietary fibre than gluten-containing pasta. Another study reported by Rosell and Matos (2015), most of the gluten-free foods such as gluten-free breads, pasta products and flours had lower dietary fibre.

2.3 The demand of gluten-free food products

Recently, the accessibility of gluten-free food products had been expanded broadly by retailers which they were easily being purchased from grocery stores, pharmacies and supermarkets (Market Research Report, 2017). The Report Summary Gluten-Free Products Market Analysis by Product (2018), it showed that there was an excessive demand for gluten-free foods among people due to the elevated number of celiac disease and gluten-sensitivity cases that emerged newly. According to Masih (2018), gluten-free food products market were increased from USD 4639.13 Million and USD 7594.43 Million in 2015 and 2020 and predicted to grow with a compound annual growth rate (CAGR) between 9.0% and 10.2% during 2016-2022. In spite of high growth due to demand of celiac disease patients, the number of gluten-

free food products not only increased by medical purposes but also increased for the sake of health reasons ranging from assisting in weight loss to management of other illnesses such as irritable bowel syndrome and inflammation among healthy people (Gaillard, 2016).

Moreover, there was an enormous consumption of gluten-free food products especially in bakery products. The demand of bakery products such as breads, pasta products, biscuits and cakes were highly increased among people nowadays (Rosell & Matos, 2011). Similarly, Kulai and Rashid (2014), also attempted that bread was one of the famous food product that has been consumed by people globally. Another interesting study by Sobota et al., (2015), reported that pasta products are well-known foods and has been consumed widely among people in the world as these products can maintain its quality in a long time, convenience, and easily to store. Recent study also found that pasta products such as spaghetti, lasagne sheet and others had the simple cooking method and good taste (Palavecino et al., 2018).

In Malaysia, there was a shift in food consumption pattern among Malaysian where there was an increasing demand for wheat-based products as the main foods as these foods can contribute to their energy (Sheng et al., 2008). Bakery industry in Malaysia was expanding widely and positively with approximately of thousands of bakery products suppliers (Malaysian-German Chamber of Commerce and Industry, 2016). For instance, in the similar report, it stated that breads, pastries and other bakery products were the most popular food products because of their convenience and quickly when being served especially among Malaysian workers whom always busy with their works (Malaysian-German Chamber of Commerce and Industry, 2016). In fact, the demand of gluten-free food products among Malaysian was still low and mostly encouraged on behalf of body weight loss and other health reasons

instead of having celiac disease (South Australian Food Innovation Centre, 2010).

2.4 Cost of gluten-free food products

The cost of gluten-free food products nowadays were increased due to high demand among people and production costs in the past years. There were a lot of studies that claimed gluten-free food products were far more expensive than gluten-containing food products. In a study by Stevens and Rashid (2008), they confirmed that gluten-free food products were more expensive than gluten-containing food products and can affect the financial of people especially among celiac disease patients because gluten-free diet should be consistent throughout their life.

Another declaration by do Nascimento et al., 2014, the prices of all gluten-free food products were higher and can be an issue among those people that consumed gluten-free food products. On the other hand, the gluten-free food products were likely to be a burdensome to people and more costly compared to the gluten-containing food products (Capacci, Leucci, & Mazzocchi, 2018; Fry, Madden, & Fallaize, 2018).

CHAPTER 3

METHODOLOGY

3.1 Sampling design and sample selection

Purposive sampling method was used as sampling design in this research project as being shown in Figure 1. Firstly, this study was conducted in four major grocery stores in Federal Territory of Kuala Lumpur namely Cold Storage, Jaya Grocer, Sam's Groceria as well as Mark and Spencer. Four of the grocery stores were purposively selected based on specific criteria such as time friendly and only these grocery stores stock organic and healthy foods including gluten-free food products which enable the study to meet the objectives effectively. In fact, Federal Territory of Kuala Lumpur was known as the biggest capital city in Malaysia where high number of grocery stores were strategically located (L'Etang, Johansson, & Ottestig, 2011). From this four grocery stores, a list of food products that were labeled with "gluten-free" followed by another gluten-containing food products based on the same category had been chosen as samples in this research project. There were eight type of food products that were chosen including bread mix, brownies mix, chocolate cake mix, all-purpose flour, spaghetti, macaroni, lasagne sheet, and biscuits. The purpose of selecting these products was based on Malaysian Dietary Guidelines by Ministry of Health Malaysia which cereals and cereals-based products were the most valuable sources of human energy.

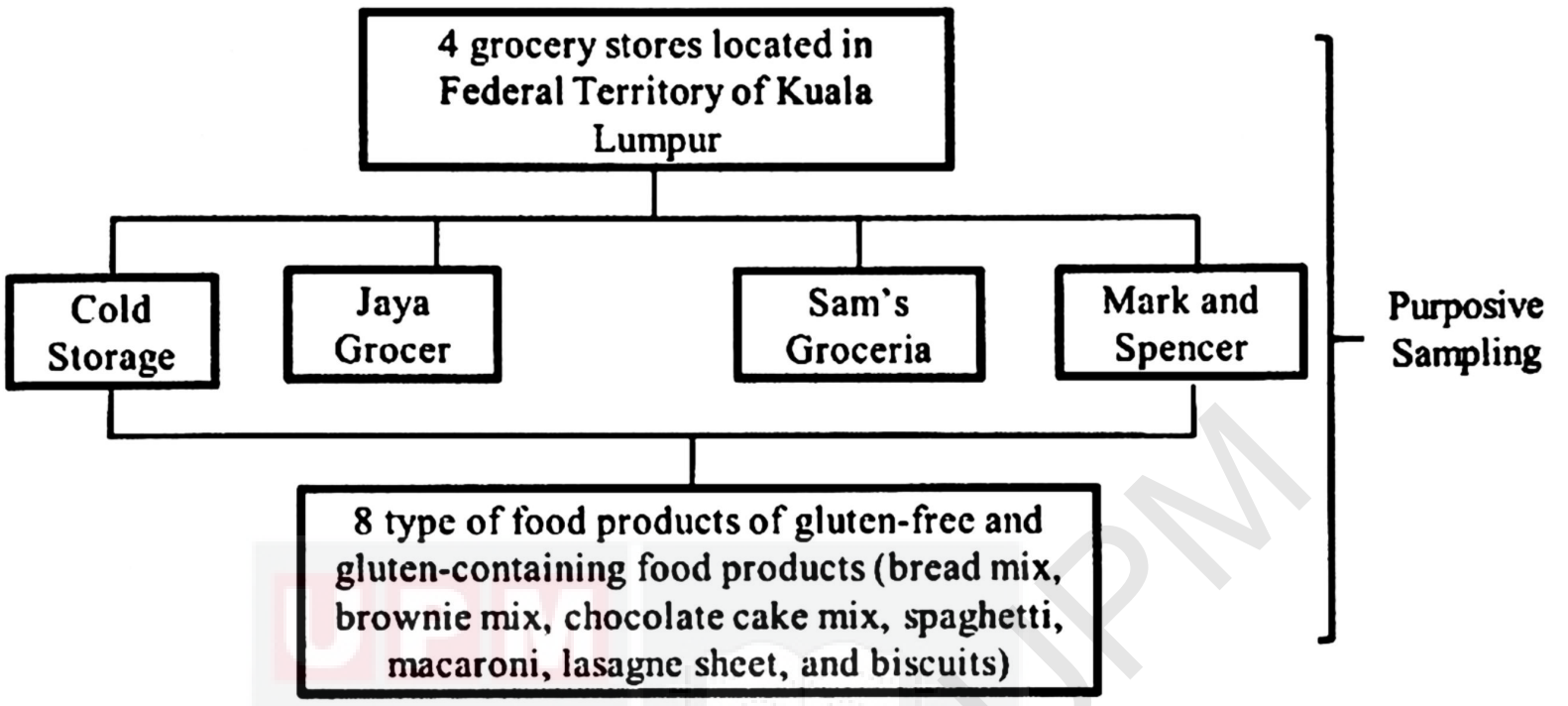

Figure 1: Flow chart of sampling design and sample selection

3.2 Sample size determination

Determination of the samples in the grocery stores was assessed directly during data collection and the number of samples was added based on their type of food products from the four different grocery stores. The gluten-free food products and gluten-containing food products such as bread mix, brownies mix, chocolate cake mix, all-purpose flour, spaghetti, macaroni, lasagne sheet, and biscuits were categorized according to their types whether it was gluten-free or gluten-containing. The total number of samples was 106 food products; gluten-free food products (n = 41) with gluten-containing food products available from grocery stores (n = 65).

3.3 Measurement

The nutritional composition (energy, carbohydrate, protein, fat, and dietary fibre) based on Nutrition Information Panel and cost per 100g between gluten-free and gluten-containing food products were determined and recorded to compare the differences between both food products. Nutritional information panel and the cost were photographed according to the type of food products.

3.4 Data analysis

The statistical analysis was performed by using IBM SPSS Version 23.0. Independent-samples *t*-test was used to compare the differences between nutritional composition (energy, carbohydrate, protein, fat and dietary fibre) based on Nutrition Information Panel and cost per 100g of gluten-free food products and gluten-containing food products of bread mix, brownies mix, chocolate cake mix, all-purpose flour, spaghetti, macaroni, lasagne sheet, and biscuits respectively. The results were expressed as mean and standard deviation. The level of statistical significance was set at $p<0.05$.

CHAPTER 4

Results and Discussion

The nutritional composition and cost of the 106 food products were determined and compared; gluten-free food products (n = 41) with gluten-containing food products available from grocery stores (n = 65). Table 1 shows the differences in mean for energy between gluten-free and gluten-containing food products (n = 106). The food products include bread mix, brownie mix, chocolate cake mix, all-purpose flour, spaghetti, macaroni, lasagne sheet, and biscuits.

4.1 Energy content

Regarding energy content, there were no significant differences in energy content between gluten-free and gluten containing bread mix, chocolate cake mix, all-purpose flour, macaroni, lasagne sheet, and biscuits. However, significant differences were found in energy content between gluten-free and gluten-containing brownie mix ($p = 0.045$) and spaghetti ($p = 0.002$). In brownie mix, the mean energy content for gluten-free was 417.50 ± 10.31g/100g and 392.83 ± 19.63/100g for gluten-containing while in spaghetti, the mean energy content for gluten-free was 368.33 ± 15.04g/100g and 354.61 ± 7.03/100g for gluten-containing. The findings showed similar results with the previous finding which stated that there were significant differences in energy content of gluten-free brownie mix and spaghetti between their gluten-containing, respectively (Missbach et al., 2015).

The higher energy content of gluten-free food products could be attributed to other ingredients used in the formulation especially on alternative flours and starches such as maize, rice, corn, potato, cassava, and rice starches that could improve the viscosity and elasticity as well as created a favourable texture of the gluten-free dough and the finished product (Allen & Orfila, 2018). Previous study found that the total energy intake was higher in celiac disease adolescents that consumed gluten-free food products than in normal adolescents (Penagini et al., 2013).

Table 1: Differences in mean for energy between gluten-free and gluten-containing food products

Food products	***n***	**Mean (g)**	***SD***	***t*-value**	***p*-value**
Bread mix	**16**				
Gluten-free	7	329.29	52.36	-1.110	0.287
Gluten-containing	9	352.38	25.51		
Brownie mix	**11**				
Gluten-free	5	417.50	10.31	2.331	0.045
Gluten-containing	6	392.83	19.63		
Chocolate cake mix	**7**				
Gluten-free	3	380.33	1.53	-0.724	0.501
Gluten-containing	4	382.75	5.50		

SD = standard deviation

Table 1 (Cont.): Differences in mean for energy between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
All-purpose flour	**10**				
Gluten-free	3	323.33	62.18	0.074	0.943
Gluten-containing	7	319.93	67.95		
Spaghetti	**30**				
Gluten-free	12	368.33	15.04	3.377	0.002
Gluten-containing	18	354.61	7.03		
Macaroni	**15**				
Gluten-free	5	357.20	8.44	0.704	0.494
Gluten-containing	10	354.30	7.07		
Lasagne sheet	**9**				
Gluten-free	3	363.00	7.81	2.001	0.085
Gluten-containing	6	354.17	5.49		
Biscuits	**8**				
Gluten-free	3	472.67	63.50	-1.168	0.287
Gluten-containing	5	508.80	25.99		

SD = standard deviation

4.2 Carbohydrate content

Based on Table 2, non-significant differences were found for carbohydrate content between gluten-free bread mix, brownie mix, chocolate cake mix, macaroni, lasagne sheet, and biscuits. Meanwhile, carbohydrate content of all-purpose flour ($p = 0.001$) and spaghetti ($p < 0.001$) were significantly difference between both food products. In all-purpose flour, the mean carbohydrate content for gluten-free was 82.73 ± 2.53g/100g and 71.60 ± 3.11/100g for gluten-containing while in spaghetti, the mean carbohydrate content for gluten-free was 77.88 ± 4.04g/100g and 71.56 ± 3.47/100g for gluten-containing.

The higher value of carbohydrate content is in accordance with the uses of alternative flours and starches such as maize flour, rice flour, corn starch, and rice starch as additives in gluten-free food products that were related to its carbohydrate content (Miranda et al., 2014). Previous studies have shown similar reason when the gluten-free food products use alternative flours and starches in their formulations, gluten-free food products will contain high amounts of carbohydrate content than gluten-containing food products (Calvo-lerma et al., 2019; Miranda et al., 2014). Furthermore, the addition of starches in the formulation of gluten-free food products has been shown to improve the viscoelasticity and texture of the dough and the finished products (Benavent-gil & Rosell, 2019). This is reflected in the emerging use of different grains to formulate new and better quality gluten-free food products (Melini & Melini, 2019).

Table 2: Differences in mean for carbohydrate between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Bread mix	**16**				
Gluten-free	7	69.94	15.00	-0.019	0.985
Gluten-containing	9	70.05	5.23		
Brownie mix	**11**				
Gluten-free	5	83.95	3.54	0.291	0.778
Gluten-containing	6	83.95	1.65		
Chocolate cake mix	**7**				
Gluten-free	3	84.97	4.37	1.056	0.339
Gluten-containing	4	81.88	3.42		
All-purpose flour	**10**				
Gluten-free	3	82.73	2.53	5.413	0.001
Gluten-containing	7	71.60	3.11		
Spaghetti	**30**				
Gluten-free	12	77.88	4.04	4.573	<0.001
Gluten-containing	18	71.56	3.47		
Macaroni	**15**				
Gluten-free	5	73.78	4.21	0.829	0.422
Gluten-containing	10	71.85	4.27		

SD = standard deviation

Table 2 (Cont.): Differences in mean for carbohydrate between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Lasagne sheet	**9**				
Gluten-free	3	74.63	2.47	2.041	0.081
Gluten-containing	6	72.23	1.20		
Biscuits	**8**				
Gluten-free	3	71.93	11.05	1.339	0.229
Gluten-containing	5	64.34	5.43		

SD = standard deviation

4.3 Protein content

Protein content was significantly lower in gluten-free bread mix ($p = 0.020$), chocolate cake mix ($p = 0.037$), all-purpose flour ($p = 0.001$), spaghetti ($p < 0.001$), and biscuits ($p = 0.001$) (Table 3). In bread mix, the mean protein content was 6.73 ± 3.99g/100g for gluten-free and 11.48 ± 1.92g/100g for gluten-containing, whereas the mean protein content for gluten-free chocolate cake mix was 3.57 ± 0.85g/100g and 5.43 ± 0.87g/100g for gluten-containing. The mean protein content for gluten-free all-purpose flour was 3.57 ± 2.71g/100g and 10.91 ± 1.68g/100g for gluten-containing. The mean protein content for gluten-free spaghetti was 8.54 ± 1.28g/100g and 12.27 ± 1.12g/100g for gluten-containing and the mean protein content for gluten-free biscuits was 2.87 ± 0.40g/100g and 7.18 ± 1.26g/100g for gluten-containing.

However, the differences between protein content were not significant in brownie mix, macaroni, and lasagne sheet ($p > 0.05$). The low amount of protein

content in gluten-free food products can be indicated by their formulation because in gluten-free food products, poor ingredients of protein were used (Missbach et al., 2015; Wu et al., 2015). The low protein content appear to be resulted from the use of refined flours or starches that are not generally enriched or fortified with protein (Calvo-lerma et al., 2019). Meanwhile, these refined flours or starches made a low contribution to the recommended daily protein intake and a high contribution to the carbohydrate dietary reference intake (Allen & Orfila, 2018).

Table 3: Differences in mean for protein between gluten-free and gluten-containing food products

Food products	***n***	**Mean (g)**	***SD***	***t*-value**	***p*-value**
Bread mix	**16**				
Gluten-free	7	6.73	3.99	-2.869	0.020
Gluten-containing	9	11.48	1.92		
Brownie mix	**11**				
Gluten-free	5	3.59	0.93	-0.720	0.490
Gluten-containing	6	4.18	1.18		
Chocolate cake mix	**7**				
Gluten-free	3	3.57	0.85	-2.831	0.037
Gluten-containing	4	5.43	0.87		
All-purpose flour	**10**				
Gluten-free	3	3.57	2.71	-5.360	0.001
Gluten-containing	7	10.91	1.68		

SD = standard deviation

Table 3 (Cont.): Differences in mean for protein between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Spaghetti	**30**				
Gluten-free	12	8.54	1.28	-8.427	<0.001
Gluten-containing	18	12.27	1.12		
Macaroni	**15**				
Gluten-free	5	9.18	2.43	-2.491	0.064
Gluten-containing	10	11.93	0.58		
Lasagne sheet	**9**				
Gluten-free	3	9.73	2.25	-1.603	0.246
Gluten-containing	6	11.83	0.41		
Biscuits	**8**				
Gluten-free	3	2.87	0.40	-5.608	0.001
Gluten-containing	5	7.18	1.26		

SD = standard deviation

4.4 Fat content

Based on Table 4, there were no significant differences in fat content across all food products ($p > 0.05$). The result was contradicted from previous findings, which mostly the researchers found significant results in fat content between gluten-free and gluten-containing food products which the gluten-free food products should contain high level of fat content than gluten-containing food products. This divergence among results might be due to differences in the variability of gluten-free food products

formulations from brand to brand and a small sample size used in this study (Melini & Melini, 2019). A number of studies concluded that majority of gluten-free food products had higher fat content to improve their flavour, consistency, and appearance (Kulai & Rashid, 2014; Missbach et al., 2015).

The possible reasons for high level of fat content in gluten-free food products might be because of the addition of fats in the formulation of the gluten-free food products including butter, margarine, coconut oil, palm oil and sunflower oil which had high contribution in the composition of gluten-free food products (Calvo-lerma et al., 2019). Past studies agreed that gluten-free diet amongst celiac disease patients was an unbalanced diet because their fat intakes was commonly higher than recommended value (Castillejo et al., 2017; Sue, Dehlsen, & Ooi, 2018). Besides, another studies also reported similar findings which they found that there were significant differences in fat intake between a group of celiac disease patients and normal people (Caponio et al.,, 2008; Maggio, 2018).

Importantly, some authors have affirmed that by having excessive consumption of fats can lead to the development of diseases such as coronary heart disease and obesity (Fry et al., 2018; Kulai & Rashid, 2014). Furthermore, it has been confirmed that several gluten-free food products contain high fat content that can give negative effect on human's health which it can stimulate the metabolic imbalance in the body (Caponio et al., 2008; Saturni et al., 2010). In parallel, similar study also reported that high fats could lead to the development of atherosclerosis (Judd, Muesing, & Carolina, 2018).

Table 4: Differences in mean for fat content between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Bread mix	**16**				
Gluten-free	7	1.80	1.55	0.168	0.869
Gluten-containing	9	1.68	1.32		
Brownie mix	11				
Gluten-free	5	6.65	2.45	1.185	0.266
Gluten-containing	6	4.42	1.97		
Chocolate cake mix	**7**				
Gluten-free	3	1.67	1.65	1.292	0.253
Gluten-containing	4	3.30	1.66		
All-purpose flour	**10**				
Gluten-free	3	0.60	0.60	-1.863	0.100
Gluten-containing	7	1.46	0.69		
Spaghetti	**30**				
Gluten-free	12	2.10	1.45	1.742	0.107
Gluten-containing	18	1.36	0.36		

SD = standard deviation

Table 4 (Cont.): Differences in mean for fat content between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Macaroni	**15**				
Gluten-free	5	1.82	1.25	0.993	0.372
Gluten-containing	10	1.25	0.40		
Lasagne sheet	**9**				
Gluten-free	3	2.30	1.04	1.588	0.249
Gluten-containing	6	1.33	0.21		
Biscuits	**8**				
Gluten-free	3	19.07	11.64	-0.930	0.388
Gluten-containing	5	24.42	5.05		

SD = standard deviation

4.5 Dietary fibre content

Table 5 shows that across all gluten-free food products, only lasagna sheet was determined as having a low content of dietary fibre ($p = 0.023$). The mean dietary fibre content for gluten-free lasagna sheet was 2.47 ± 0.06g/100g and 2.97 ± 0.29g/100g for gluten-containing. The previous finding also showed similar result in which there was a significant difference in dietary fibre content between gluten-free and gluten-containing food products because during refining process, the outer layer of grain which contain a lot of fibre is being removed and only leaving the starchy inner layer only (Saturni et al., 2010). Similarly, another study also found that the substitution of

commercial starches toward wheat flour for gluten-free food products do not significantly provided adequate amount of dietary fibre content (Thompson, 2000).

With regard to low dietary fibre content, several studies also found celiac disease patients that were following gluten-free diets have low content of dietary fibre intake of nutrients as compared to a control group of people on normal diets (Shepherd & Gibson, 2013; Wild et al., 2010). Another study in Sweden, screened that the average of dietary fibre consumption amongst celiac disease patients was lower than the recommended value (Grehn et al., 2001). A study on paediatric patients with celiac disease found that children on gluten-free diets may be at higher risk of insufficient fibre intake compared to children on normal diets resulted from the utilization of low-fibre starches and refined flours in the gluten-free food products (Sue et al., 2018).

Table 5: Differences in mean for dietary fibre between gluten-free and gluten-containing food products

Food products	***n***	**Mean (g)**	***SD***	***t*-value**	***p*-value**
Bread mix	**16**				
Gluten-free	7	4.27	1.92	1.042	0.316
Gluten-containing	9	3.29	1.74		
Brownie mix	**11**				
Gluten-free	5	3.80	1.22	1.576	0.180
Gluten-containing	6	3.13	0.42		

SD = standard deviation

Table 5 (Cont.): Differences in mean for dietary fibre between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Chocolate cake mix	**7**				
Gluten-free	3	3.00	0.72	-0.348	0.742
Gluten-containing	4	3.33	1.47		
All-purpose flour	**10**				
Gluten-free	3	1.33	1.19	-0.599	0.566
Gluten-containing	7	2.13	2.11		
Spaghetti	**30**				
Gluten-free	12	2.63	1.85	-0.876	0.388
Gluten-containing	18	3.42	2.72		
Macaroni	**15**				
Gluten-free	5	2.52	1.29	-0.864	0.403
Gluten-containing	10	3.14	1.32		
Lasagne sheet	**9**				
Gluten-free	3	2.47	0.06	-2.887	0.023
Gluten-containing	6	2.97	0.29		

SD = standard deviation

Table 5 (Cont.): Differences in mean for dietary fibre between gluten-free and gluten-containing food products

Food products	*n*	Mean (g)	*SD*	*t*-value	*p*-value
Biscuits	**8**				
Gluten-free	3	1.10	1.05	0.044	0.966
Gluten-containing	5	1.06	1.32		

SD = standard deviation

4.6 Cost

Overall, this study determined that all the cost for the majority of gluten-free food products were significantly higher as compared to gluten-containing food products as being shown in Table 6, bread mix ($p = 0.017$), brownie mix ($p = 0.029$), chocolate cake mix ($p = 0.004$), spaghetti ($p < 0.001$), macaroni ($p = 0.020$), and biscuits ($p < 0.001$). In bread mix, the mean cost was 4.05 ± 2.50RM/100g for gluten-free and 0.97 ± 0.52RM/100g for gluten-containing, the mean cost for gluten-free brownie mix was 5.24 ± 0.41RM/100g and 3.12 ± 1.71RM/100g for gluten-containing, in chocolate cake mix, the mean cost was 4.33 ± 0.78RM/100g for gluten-free and 1.92 ± 0.46RM/100g for gluten-containing, and in spaghetti, the mean cost was 5.71 ± 2.29RM/100g for gluten-free and 1.38 ± 1.50RM/100g for gluten-containing. Besides, in macaroni, the mean cost was 4.46 ± 2.11RM/100g for gluten-free and 0.92 ± 0.16RM/100g for gluten-containing and lastly the mean cost for gluten-free lasagne sheet was 6.17 ± 0.58RM/100g and 2.22 ± 0.37RM/100g for gluten-containing.

The results were in line with previous which found that gluten-free food products were more expensive as compared to gluten-containing food products

findings (Kulai & Rashid, 2014; Fry et al., 2018). Another researchers also stated that, by consuming gluten-free food products, it could affect the financial status especially among celiac disease patients because gluten-free diet should be consistent throughout their life and cost could become huge over time (Capacci et al., 2018; do Nascimento et al., 2014; Stevens & Rashid, 2008). Similarly, one study claimed that more gluten-free food products were only available online and in the higher-end grocery stores than the traditional grocery store which would give persistent financial burden especially among celiac disease patients (Lee et al., 2019).

Table 6: Differences in mean for cost between gluten-free and gluten-containing food products

Food products	*n*	Mean (RM)	*SD*	*t*-value	*p*-value
Bread mix	**16**				
Gluten-free	7	4.05	2.50	3.195	0.017
Gluten-containing	9	0.97	0.52		
Brownie mix	**11**				
Gluten-free	5	5.24	0.41	2.603	0.029
Gluten-containing	6	3.12	1.71		
Chocolate cake mix	**7**				
Gluten-free	3	4.33	0.78	5.181	0.004
Gluten-containing	4	1.92	0.46		

SD = standard deviation

Table 6 (Cont.): Differences in mean for cost between gluten-free and gluten-containing food products

Food products	*n*	Mean (RM)	*SD*	*t*-value	*p*-value
All-purpose flour	**10**				
Gluten-free	3	3.33	1.53	3.022	0.086
Gluten-containing	7	0.61	0.44		
Spaghetti	**30**				
Gluten-free	12	5.71	2.29	6.278	<0.001
Gluten-containing	18	1.38	1.50		
Macaroni	**15**				
Gluten-free	5	4.46	2.11	3.748	0.020
Gluten-containing	10	0.92	0.16		
Lasagne sheet	**9**				
Gluten-free	3	6.17	0.58	12.672	<0.001
Gluten-containing	6	2.22	0.37		
Biscuits	**8**				
Gluten-free	3	7.24	5.59	1.252	0.329
Gluten-containing	5	3.12	1.46		

SD = standard deviation

CHAPTER 5

CONCLUSION, LIMITATIONS AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, this study is the first study that determined and compared the nutritional composition of gluten-free food products with gluten-containing food products available from grocery stores in Federal Territory of Kuala Lumpur, Malaysia. Briefly, this study showed that the gluten-free food products had overall similar nutritional composition with gluten-containing food products except for protein content. The findings found that the energy content was significantly higher especially in the gluten-free brownie mix and spaghetti ($p < 0.05$), and carbohydrate content was higher in gluten-free all-purpose flour and spaghetti ($p < 0.05$) than gluten-containing. In addition, low protein content was found in gluten-free bread mix, chocolate cake mix, all-purpose flour, spaghetti and biscuits ($p < 0.05$). Across all gluten-free food products, only lasagne sheet was determined as having a low content of dietary fibre ($p < 0.05$). The cost for the majority of gluten-free food products were significantly higher as compared to gluten-containing food products.

A consistent monitoring on nutritional composition of gluten-free food products is strongly encouraged in order to improve the nutritional quality in gluten-free diet. A good cooperation between nutritionist and food manufacturers in term of new reformulation of ingredients of gluten-free food products should be done regarding the lack of nutrients such as low protein and dietary fibre contents in the

gluten-free food products. Nutritionist and other health care workers also should play their roles in giving more knowledge on the gluten-free diet and the adverse health effects such as heart disease due to overconsumption of gluten-free food products toward celiac disease patients and healthy people as well as training them on how to read nutrition labelling correctly.

5.2 Limitations of the Study

There are some important limitations in this study that need to be recognized in order to improve the accuracy of the results. Firstly, a small sample size was used in this study because this study only represents the findings from four grocery stores in Federal Territory of Kuala Lumpur, Malaysia. Therefore, the findings of this study cannot be generalized to all gluten-free food products in Malaysia. Next, this study was prone to research bias due to the used of non-probability sampling method such as purposive sampling that can increase the risk of being under-reporting and over-reporting. Lastly, the nutritional composition analysis in this study was based on nutritional information panel only and correlate with some of the food manufacturers simply add up the nutritional values of the various ingredients in the foods using a standard nutrient database.

5.3 Recommendations

There are some recommendations that could be suggested for nutritionists and further research investigations. Firstly, it is important to increase the number of sample size in order to make the findings more representative and generalizable in Malaysia. Furthermore, future investigations should use a proper sampling method such as probability sampling to achieve a representative sample and provides reproducible

results within uncertainty limits. Another recommendation is, the nutritional composition analysis can be done by conducting appropriate chemical analysis to assess the nutrients in the food products individually and this gold-standard method will provide more accurate data.

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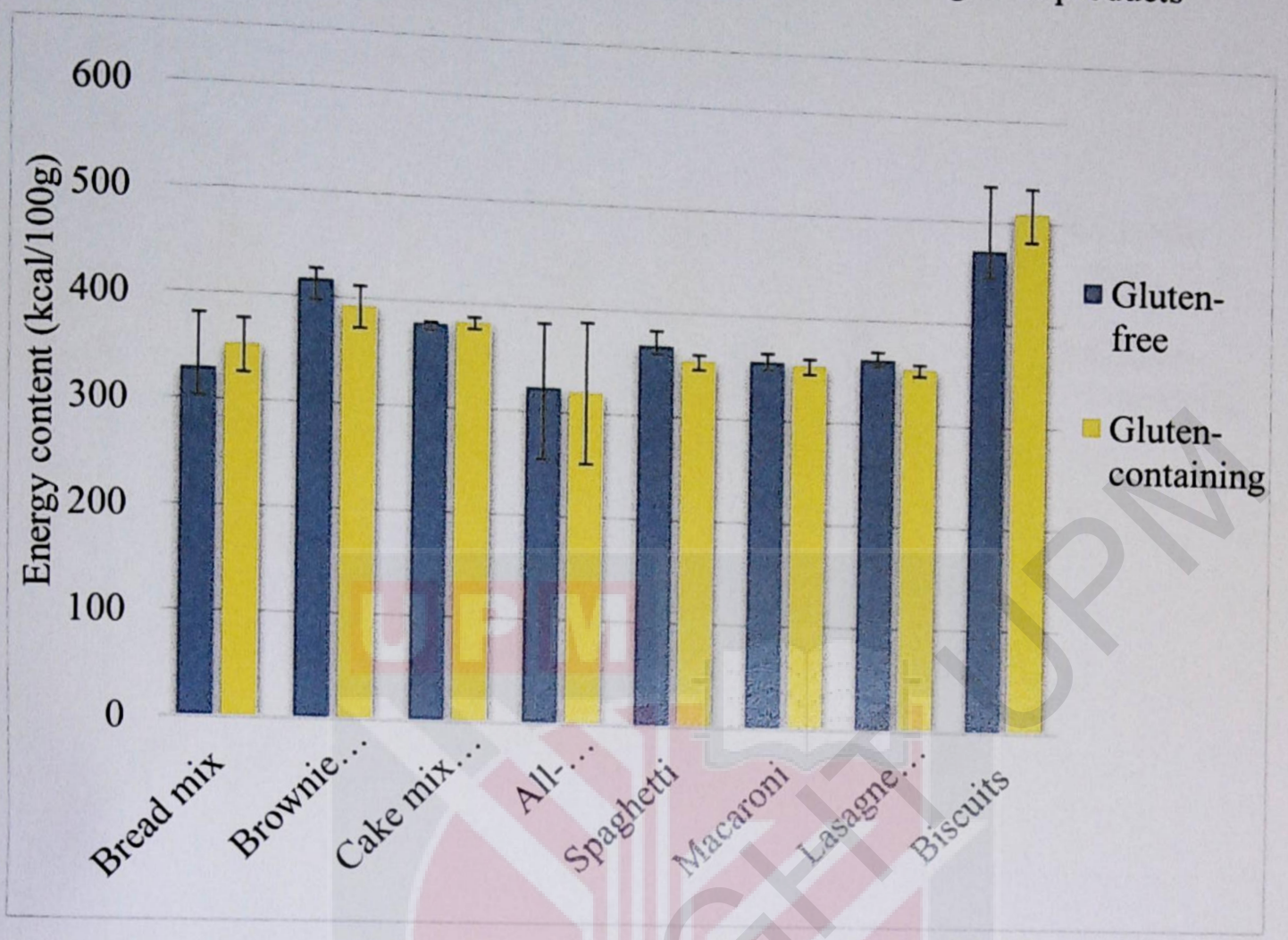
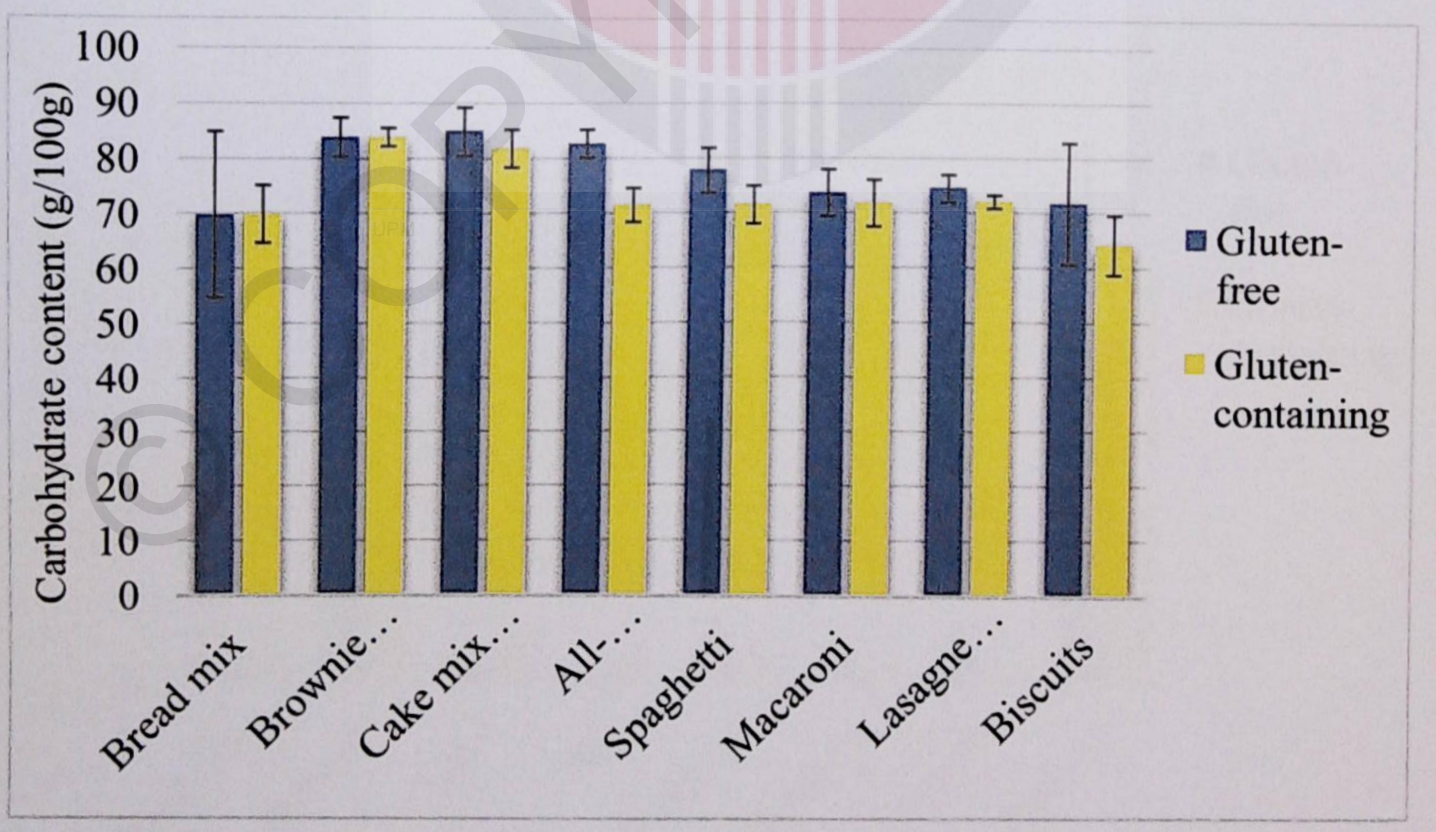
APPENDICES

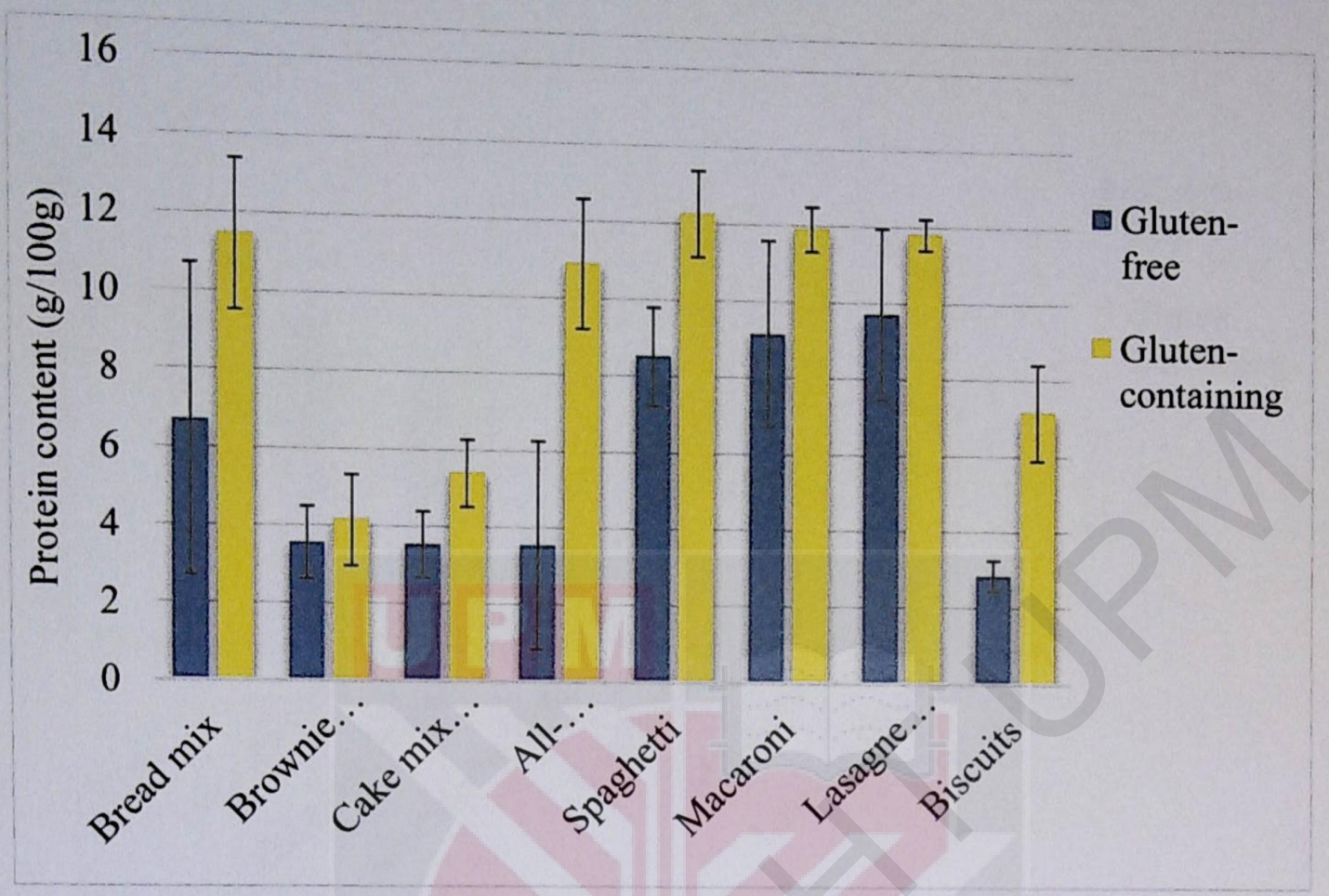
Energy content between gluten-free and gluten-containing food products



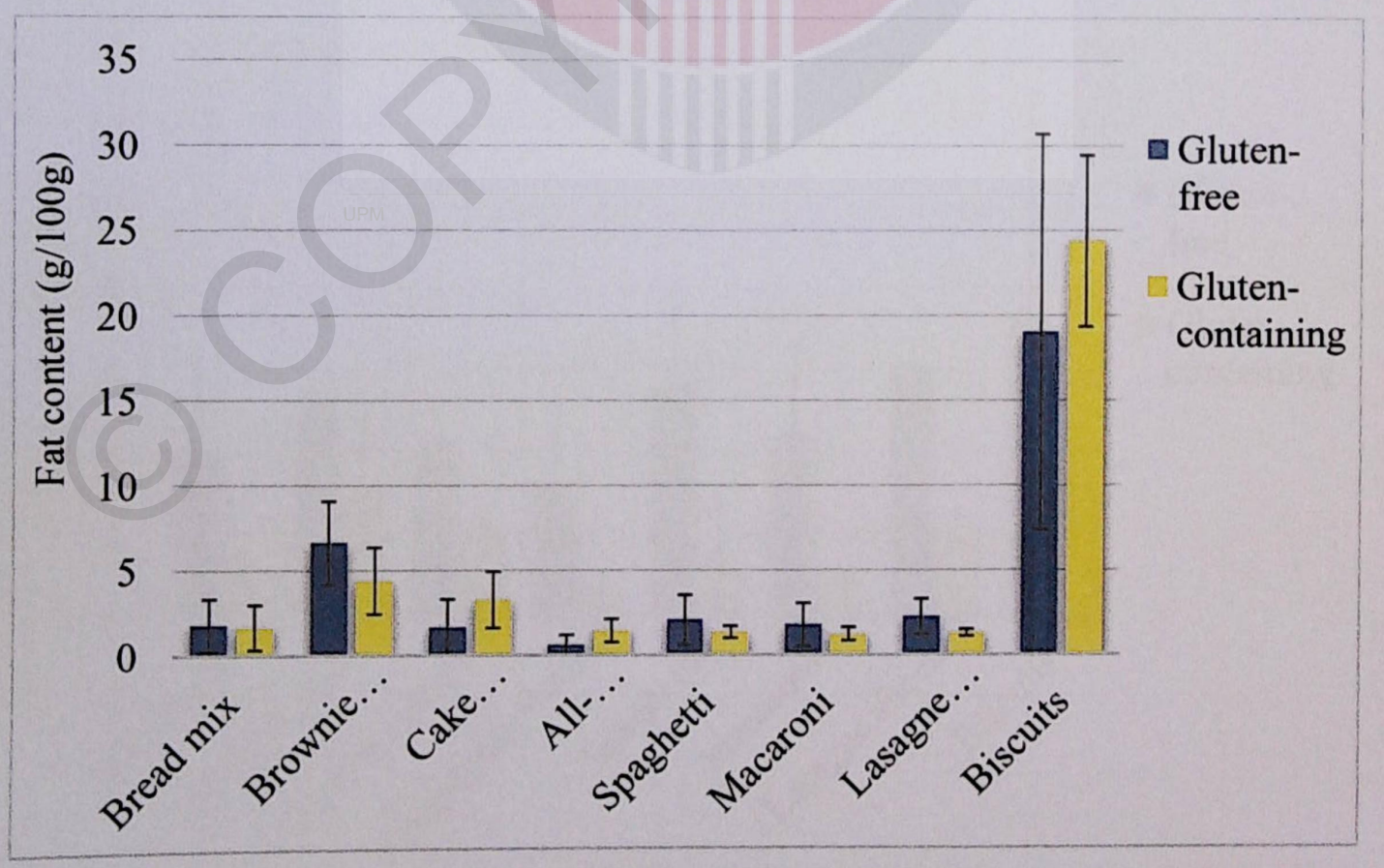
Carbohydrate content between gluten-free and gluten-containing food products



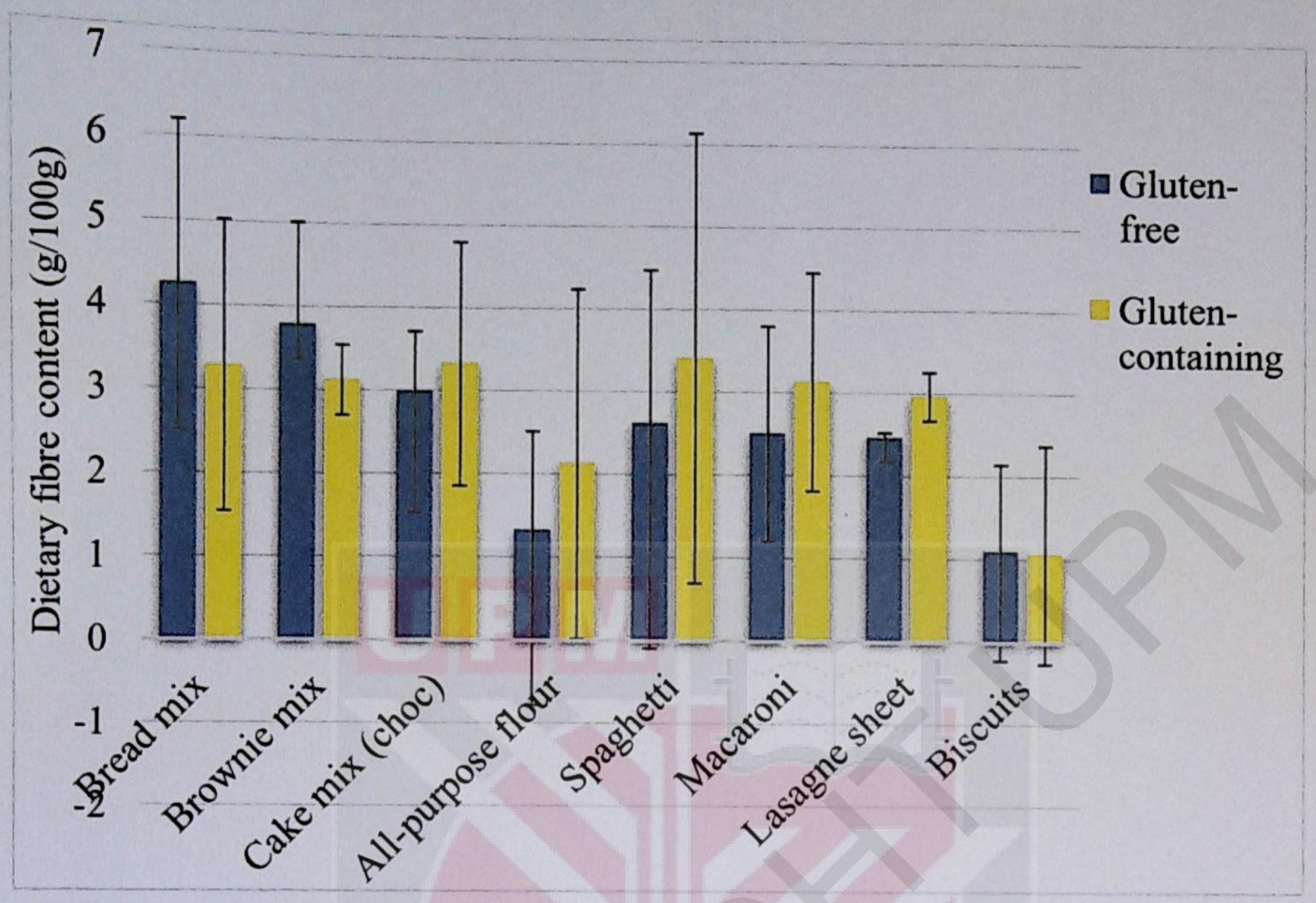
Protein content between gluten-free and gluten-containing food products



Fat content between gluten-free and gluten-containing food products



Dietary fibre content between gluten-free and gluten-containing food products



Cost between gluten-free and gluten-containing food products