Physicochemical and Functional Properties of Crackers from Different Particle Size of Baby Corn Powder.

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ABSTRACT

In recent years, baby corn have been gaining popularity among Asians because of its level of nutritious. Due to the lack of consumption food that higher in dietary fiber leads to many serious illness and wellness. The objectives of this study are to determine the physicochemical and functional properties of baby corn crackers developed using different particle sizes that were 125,250 and 500 µm. Determination of moisture, fat, fiber, ash and protein were determined according to AOAC methods. Color was determined using Chroma meter while texture properties were determined using Texture Profile Analyzer. Crackers were formulated separately to contain baby corn powder of 125,250 and 500 µm. The results showed that the crackers prepared from 500µm baby corn powder demonstrated high protein (15.56±0.44 %), dietary fiber (14.35±0.84), moisture and ash content compared to other crackers. However, the fat content was slightly higher (8.83±0.24%) than other crackers due to the larger surface area of the powder bind more oil. Furthermore, the crackers prepared using 500 µm of baby corn powder showed good in bulk density, foaming capacity and stability. The crackers prepared from 125µm of baby corn powder were good in oil and water absorption capacity. In physical traits, crackers prepared using 125µm scored mean value that are related to control crackers except hardness. In conclusion, the functional property of 500µm of baby corn powder were good in every functional properties evaluated except foaming capacity, thus this vegetable food powder is recommended to be utilized in bakery product and healthy snack foods.

Keywords: cracker, functional properties, nutritional fact, particle size, physicochemical, *Zea mays*

ABSTRAK

Sejak beberapa tahun kebelakangan ini, jagung muda semakin popular di kalangan orang Asia kerana tahap khasiatnya. Disebabkan kekurangan pengambilan makanan yang lebih tinggi dalam serat diet membawa kepada banyak penyakit dan kesihatan yang serius. Objektif kajian ini adalah untuk menentukan sifat fizikokimia dan fungsian biskut jagung muda yang dibangunkan menggunakan saiz zarah serbuk jagung meda yang berbeza. Penentuan kelembapan, lemak, serat, abu dan protein ditentukan mengikut kaedah AOAC. Warna ditentukan menggunakan meter Chroma manakala sifat tekstur ditentukan menggunakan Penganalisis Profil Tekstur. Biskut diformulasikan secara berasingan untuk mengandungi serbuk jagung muda yang bebeza saiz zarah iaitu125,250 dan 500 µm. Keputusan menunjukkan bahawa biskut yang disediakan daripada serbuk jagung bayi 500µm menunjukkan kandungan protein yang tinggi (15.56±0.44%), serat makanan (14.35±0.8416), kandungan lembapan dan abu berbanding keropok yang lain. Walau bagaimanapun, kandungan lemak adalah lebih tinggi sedikit (8.83±0.236%) berbanding keropok lain kerana luas permukaan serbuk yang lebih besar mengikat lebih banyak minyak. Tambahan pula, biskut yang disediakan menggunakan serbuk jagung muda 500µm menunjukkan ketumpatan pukal, kapasiti berbuih dan kestabilan yang baik. Keropok yang disediakan daripada 125µm serbuk jagung muda adalah baik dalam kapasiti penyerapan minyak dan air. Dalam ciri fizikal, biskut yang disediakan menggunakan nilai min skor 125µm yang berkaitan dengan biskut kawalan kecuali kekerasan. Dalam kesimpulan, sifat fungsian 500µm serbuk jagung bayi adalah baik dalam setiap sifat fungsi yang dinilai kecuali kapasiti berbuih, oleh itu serbuk makanan sayuran ini disyorkan untuk digunakan dalam produk bakeri dan makanan ringan yang sihat.

Kata kunci:biskut, fakta pemakanan. fizikokimia, saiz zarah, sifat berfungsi, *Zea mays*

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DECLARATION

I hereby declare that the work embodied in this report is the result of the original research except the excerpts and summaries that I have made clear of the sources.

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LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA : Analysis of Variance

CVD : Cardiovascular disease

NVD : Non communicable disease

TSS : Total Soluble Solid

OAC : Oil absorption capacity

WAC : Water absorption capacity

TDF Total Dietary Fiber

CHAPTER 1:

INTRODUCTION

1.1 Research Background

This research was carried out with the previous studies evidence which indicated the powdered form of vegetable in this case, *Zea mays* baby corn have the same level of nutritive profiles compare to the fresh one. Besides that, vegetable dry powders where have been used in many industries to promote benefits. For instance, these ingredients were widely used in non-food product industries too for example, perfumery and cosmetic sector.

Due to vegetable increased level of moisture around 80%, it is highly perishable goods that deteriorate over a short period of time if improperly handled. The development of spoilage microorganisms and browning reactions in the substance matrix, both enzymatic and non-enzymatic can be stopped by using the elimination of water from vegetable technique. Preserving the structure of vegetables, there will be changes in sensorial characteristics and the nutritional value. The market for vegetables has actually achieve a rapid growth rate for most countries worldwide (Karam et al., 2016)

Since bakery snacks like cakes, cookies, and crackers are commonly eaten around the world, adding nutrients to them is an important way to improve people's health. This can be accomplished by incorporating dried vegetable powder into the cracker recipe. In comparison to other crops, baby corn has a rich source of crude fiber 5.7 % dry basis and dietary fiber 29.2 % dry basis. (Hooda, & Kawatra,2013)

This research was mainly focused on the bakery products which are crackers, these are one type of food that is easy to consume. Furthermore, crackers are complementary foods that are common among Malaysians, including youngsters. As a result, including food fiber in bakery products is expected to boost food fiber consumption, especially among teenagers who enjoy snacking. Fiber-enriched crackers, such as wheat bran fiber, are also available on the market. There are no references, however, that provide information on the particle sizes of baby corn flour as dietary fiber sources, particularly for baking products.

Based on this condition, more research into the particle sizes of a baby corn flour as a fiber source in crackers is needed. Then, to know baby corn flour can work functionally and more effectively compared to wheat flour into production of bakery products. The goals of this research were to use the nutrient content of baby corn in cracker processing, as well as to assess the formulations, properties, and possible nutritional benefits of the new cracker products. The fiber-enriched crackers physicochemical, nutritional, and functional properties will be analyzed.

1.2 Problem Statement

Snack food consumption has risen as a result of urbanization and modernization. However, most snacks have a high fat, glucose, and salt content, as well as a poor dietary fiber content, which may contribute to health problems. (Lloyd-Williams, F., et al., 2008). As a result, market preference for nutritious snacks is growing because of their excellent eating consistency and superior nutritious properties, snack crackers can be considered one of the most desired.

The lack of palatability of fiber-rich foods may be the primary cause for lower fiber intake. Only foods obtained from grains, fruits, vegetables, nuts, and legumes naturally contain dietary fiber. According to Hooda, Santosh, and Asha Kawatra (2013), baby corn is a great source of different nutrients such as protein, crude fiber, sugars, and dietary fibers, and its nutritional value is equal or even better than other commonly used vegetables.

The baby corn is been highly harvested vegetable in Malaysia, but there are a little number of processed foods incorporated young corn were available in market. From the report of Malaysia - Maize production quantity shows that in 2020, corn production for Malaysia was 58000 tons. Malaysian corn sales rose from 5 thousand tons in 1971 to 58 thousand tons in 2020, increasing at a 13.96 percent annual rate.

Baby corn has been touted as one of the healthiest veggies can add to our daily cooking dishes. Other than that, baby corn also can dry and a produce new product which more beneficial to consumers. Baby corns are a higher in folate sources and vitamin B is claimed to play a crucial role in preventing the defect of neural-tube birth within the fetus. (Hooda, and Kawatra,2013) The crackers also can be a healthy breakfast for pregnant ladies in their busy working schedule. Pregnant women might want to feature baby corn in their pregnancy diet for healthy nutrition.

Baby corn is a high in nutrient vegetable. In addition, baby corns are full of vital antioxidants too. A half cup serving is said to provide 4% of the daily vitamin A and iron requirements, as well as 2% of the daily vitamin C requirements. .Dietary fiber, when combined with carbohydrate-rich foods, has been linked to a lower rate of diseases such as cancer, heart disease, diabetes, infections, and respiratory diseases (Elleuch et al. 2011). As a result, dietary recommendations often recommend diets high in fiber, such as vegetables and grains, to promote a balanced lifestyle. Fiber incorporation does not only have health benefits; it also imparts functional properties to foods such as increased water and oil retaining capability, emulsion and foam forming, texture, modification of eating properties, structure stability, and shelf-life extension.

1.3 Hypothesis

1.3.1 H_0: There are no significant difference between physicochemical properties and functional properties of baby corn crackers and different particle size of baby corn powder.

1.3.2. H_1: There are significant difference between physicochemical properties and functional properties of baby corn crackers and different particle size of baby corn powder.

1.4 Significance of Study

Consumers always prefer snack meals and ready-to-eat breakfast cereals. They do, however, often lack a healthy dietary profile, which, when combined with a lack of exercise, can lead to obesity. Obesity has been contributed to an uptick in mortality and is a growing burden on the health-care system. (A.S.Bawa,J.S.Sidhu, 2003) As a best solution for this problem, this study is going to produce snack food that incorporated with a high level of fiber ingredients. The *Zea Mays* baby corn flour also have capability to work internal functions in the production of bakery goods because of incorporation with high dietary fiber content.

Thus, the dietary fiber content of baby corn was extensively used in the production of crackers in this research. All of the related physicochemical analysis and functional properties of crackers will be analysed to use the formulation for being a successful commercial formulation. This research will generate a new food product that is beneficial to human health. This research was developed to produce a healthy and nutritious crackers to replace it with unhealthy snack foods.

1.5 Objectives

1.5.1 To determine the influence of different particle size of baby corn powder on physicochemical properties of crackers.

1.5.2 To evaluate the functional properties of baby corn crackers from different particle size of baby corn powder and the functional properties of baby corn flour compared with wheat flour.

1.5.3 To analyze proximate composition of cracker develop from selected baby corn powder particles.

CHAPTER 2:

LITERATURE REVIEW

2.1 Baby Corn

According to Kumar.et al., 2015, baby corn known as the ear of maize and it's also named as baby corn, mini corn, or candle corn (*Zea mays* L.). After wheat and rice,the third most essential cereal crop is corn in this world. Maize is divided into separate categories based on the endosperm of the seeds, with baby corn being cultivated for vegetable purposes (Kumar et al., 2015). Depending on the growing season, baby corn is an unfertilized maize cob harvested within 1 day of silk emergence. Because of its softness and crunchiness, it is very delicious, appetizing, and easily can eat as a raw food with full of nutrients (Pandey et al., 2000).

2.1.1 Characteristics of Baby Corn

Baby corn is a unique choice for a variety of conventional and continental dishes because of its high nutritional value, eco-friendliness, attractiveness, fine, sweet flavor, taste, color, and crisp nature. Baby corn is a viable crop for diet diversification, as it brings a unique flavor to a variety of other dishes. Green, smooth, tasty, nutritious, palatable, and high digestibility characterize freshly harvested baby corn (Kumar.et al., 2015). According to Dass et al., 2008, baby corn is a gain of popularity among both international markets and domestic. It also has export potential and processing. Growing maize for vegetable purposes is a fascinating recent phenomenon.

2.1.2 Nutritive Value of Baby Corn

Baby corn is a tasty, utilized as a healthy, and decorative crops that is cholesterol-free. It's a low-calorie vegetable that's still high in fiber. In terms of minerals, one young corn can be equivalent to an egg.(Pandey et al., 2000)

Table 2.1: The nutritional content of baby corn

Components	Amount
Sugar	0.016-0.020%
Protein	15-18%
Phosphorus	0.6 - 0.9%
Fibre	3-5%
Potassium	2-3%
Ascorbic acid	75-80 mg/100g
Calcium	0.3-0.5%

Sources: Rani, et al., 2019

The table 2.1 shows the nutritive value of baby corn, the sugar content of baby corn is about 0.016 to 0.020 percent and the protein content is about 15 to 18 percent. Furthermore, the fiber content of a baby corn is about 3 to 5 percent and the potassium content is about 2 to 3 percent. In a baby corn there are a little amount of ascorbic acid and calcium as the table showed (Rani, et al., 2019).

According to Singh et al., 2006, it is likely the only crops free from pesticides residues. Baby corn is insect-free and disease-free, and its nutritious value is equal to a variety of high-priced vegetables. Baby corn is an ideal fodder crop because of it is higher in crispiness, sensory quality, nutritional value, and it can be used at any level of growth.

A comparison of dried young and fresh baby corn was carried out by (Wan Rosli et al., 2012). The fresh baby corn comprised 2.60 percent protein, but dried baby corn included a significant quantity of protein (25.58 percent). Plants have a huge variety of different protein concentrations. (Hogan et al., 1955) found that the average proportion of protein in maize is about 10%. Fresh baby corn had a crude lipid content of 0.51

percent, which was substantially lower (P lower than 0.05) than dried young corn, which had a crude lipid content of 3.67 percent. The amount of ash in dried young corn was low which is 0.44 percent, and the percentage of ash in dried young corn was also very low (3.74 percent).

2.1.3 Utilization of Baby Corn in Food and Agriculture Sector

According to Asaduzzaman et al., 2014, the full ear of baby corn is an edible vegetable. A baby corn can eat raw or fried. According to Karam et al., 2016, in the soda industry, powders of fruits and vegetable used for intermediate ingredients as practical food additives enhancing the nutritional content of foodstuffs, as flavoring agents in yogurts, ice creams, and fruit bars as natural colorants. For example, explained how adding fruit powders of blueberry and cranberry as colorants made white cornmeal breakfast cereal more appealing. Powders of guava and cashew-apple are useful as high dietary fiber additives fortifiers in the food industry. Powders of fruit and vegetable can also be used in dry soups, instant noodles and other dishes. They are also used in scent and cosmetics such as powder of Kaempferia galangal as nutraceutical instruments.

Corn flour is a key component in determining thickness and viscosity, which is a crucial indicator for determining the final body and texture of a liquid product such soup (Ravindran and Matia-Merino, 2009). Antifungal, antibacterial, heart protecting, and antioxidant effects are all found in garlic powder (Ayoka et al. 2016). Coriander powder has anti-diabetic properties. It has anti-inflammatory, antioxidant, and antibacterial activities in India (Rathore et al. 2013). Mango powder aids digestion, combats acidity, and contains potent antioxidants that promote regular bowel movements, avoiding constipation and gas.

2.2 Dehydration of Vegetables

The theory of dehydration preservation is to reduce the moisture content of a substance to a degree that microorganisms cannot develop and ruin it. Anis Jauharah, 2014 indicated that drying can lower moisture content by approximately 93 precent of total moisture available in fresh baby corn. Fresh vegetables are high in water content which are prone to spoilage. The sun-drying of vegetables is the earliest known form of dehydration. To longer the shelf life of baby corn, it can treated in many ways. Canning, dehydration, and freezing are the most effective preservation methods for extending shelf life. Dried baby corn can be packaged in vacuum, polythene or tetra packs for longer the storage period. Products made from dried baby corn have been shown to have the same organoleptic qualities as those made with fresh baby corn.

Yadav,et al.,2014 states that vegetables are dehydrated to retain flavor and nutrients. Osmotic, Convective, microwave, fluidized bed, freeze-drying, and vacuum techniques are the examples of drying methods. To maintain the quality of the vegetables, method such as acid treatment, the application of coatings and blanching are frequently used. Though the drying process of industry is designed to preserve quality of food to the greatest extent possible, certain nutrients, especially heat-labile nutrients like flavonoids, vitamin, and beta carotene may be degraded during pre-processing and drying.

The grinding or drying medium, as well as the raw physical attributes, structure, cultivar-field harvested mechanically or manually and method of processing (conventional or organic), all influence consistency of a vegetable powder. Quality degradations such as shrinkage, crystallisation, puffing, decreased rehydration capability, and loss of flavour, colour, fragrance, and nutritional properties are addressed by drying and grinding operations. (Karam, et al, 2016)

2.3 Particle Size of Dehydrated Vegetables

According to Yusraini, 2020, particle size influenced the functional properties and physicochemical of the vegetable powder. If the particle size was lowered, the fiber content reduced, while proteins and fat became concentrated in the smaller fractions. Baby corn powder were also proved that could passes through three size of the sieve number which are 40, 50, and 80 mesh. (fig2.3)

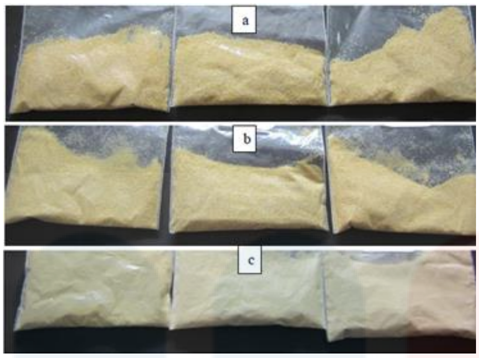

Figure 2.3: Baby corn flour of different size of particle passed the sieve number (a) 40 (b) 50 (c) 80 (Yusraini, 2020)

Corn flour with a higher number of passes through the sieve has a lighter color toward yellowish white, a smaller bulk density, and a rise in oil absorption. The increase in fat absorption triggered by a reduced in the dietary fiber’s size of particle. The ability to absorb oil can be reduced due to the greater particle size. As a result, the decreased young corn flour’s particle size increases the surface area sufficient for oil absorption.

According to Bourré, L., Frohlich, P., Young, G., et al. (2019), finer flours showed lower water absorption capacity (WAC), more starch degradation, average viscosities and higher peak. Navy bean flour had a larger particle size distribution, reduced starch degradation, greater WAC, and lower peak and final viscosities as a result of the hull.

Dietary fiber's functional qualities are improved as particle sizes are reduced (Chen, Gao, Yang, & Gao, 2013). By raising the surface development degree, dietary fiber particle size reduction allows for an improvement in water-holding capacity. Because moisture is engaged in protein denaturation, starch gelatinization and the synthesis of both taste and colors associated compounds, this aspect is particularly crucial in the bread process of production. Furthermore, the addition of moisture delays the retro gradation of starch in bread, preventing it from staling. (Rosell and colleagues, 2009)

2.4 Functional Properties of Different Particle Size of Vegetable Powder

Vegetables are abundant in vitamins, dietary fiber, bioactive compounds and minerals (Brewer, 2011). However, vegetables are highly perishable and easily loose its nutritional value in a short period of time. Dried vegetable powder prolong the shelf-life and utilised as an ingredient in many food products, including beverages, salad dressings, bakery products and gluten-free diets. Furthermore, it can be also used as a functional food additives for improving the nutritional values of food products (Jiang & Zhang, 2013).

The properties of vegetable powder used in food products are highly important because they affect the product attributes. The properties of functions that are oil and water holding capacity, particle diameter emulsion capacity and stability, playing essential role chemical and physical properties during their preparation, processing, and storage (Ahmedna, et al., 1999). Modifications in viscosity, texture, gelatinization, structure, and sensory qualities of the final products could be related to changes in functional properties (Aydin, E. et al., 2015).

2.4.1 Water Absorption Capacity

In a cracker formula, water absorption levels typically range from 150–154 percent. Any increase in flour's enzymatic activity will enhance water holding capacity and the maillard reaction when producing flour. Factors that influence a flour's water holding capacity include starch, which accounts for about 46percent of total total hold water. Following that, pentosans in flour account for about 23percentage of total water absorbed. Then there are proteins, which account for around 31percent of total water absorbed. When vital wheat gluten is added to the dough, it improves water absorption and dough stability (Sumnu & Sahin, 2008). Other water-binding substances, such as fibre, eggs, and so on.

A composite flour that have a high water holding capacity, indicating that they can be utilized in the formulation of some foods, such as dough and bakery items. Increases in water holding capacity have always been linked to increased amylose solubility and leaching, as well as crystalline structure degradation in starch. More hydrophilic elements, such as polysaccharides, may be found in flour with a high water absorption rate. Proteins can interact with water in foods because they are both hydrophilic and hydrophobic.

2.4.2 Oil Absorption Capacity

According to the studies of Iwe et al., 2016, oil holding capacity is about non-polar protein side chain binding with fat. Oil binding capacity has a characteristics functionally which can aids in the improvement of physical sensation of food in the mouth, while preserving the taste of food stuffs. In diets with an increase content of protein, the rate of oil absorption is extremely high. Protein's ability to absorb water and oil in food is influenced by intrinsic characteristics such as protein structure, amino acid content, and surface hydrophobicity. Flours that have the capacity to absorb with oil are beneficial to food product which requires the maximum oil binding capacity such as the manufacturing of pastries. When employed in food preparation, the flour's ability to absorb oil makes it ideal for improving flavor and eating quality. (Suresh and Samsher, 2013).

The existence of non-polar side chains, which may bond the oil hydrocarbon side chains in meals and flours, could be one cause for the increase in oil binding capacity of flours. Flours having a high oil binding capacity content may be useful in food structural interactions, such as extending shelf life, retaining flavor and improving palatability, especially in bakery products where fat absorption is desired (Suresh et al. 2015).

2.4.3 Bulk Density

The variation in bulk density of foods could be attributed to variations in starch content. The higher the starch content, the greater the likelihood of an increase in bulk density. Furthermore, bulk density is affected by factors such as geometry, method of measurement, particle size, surface characteristics, and solid density of the materials, and it can be improved when the particles are smaller, properly tapped/vibrated, compactible, and packaged properly (Iwe et al., 2016).

According to recent research, the initial water content of flours may influence its bulk density. The high bulk density of flours suggests that they are suitable for use in food preparation. Low bulk density, on the other hand, would be useful in the formulation of complementary foods (Suresh and Samsher, 2013). Starch is the main structural and bulking agent in many food products, such as biscuits, bread, cakes, and pastries.

2.4.4 Swelling Capacity

In some food products, such as bakery goods, swelling capacity (index) is considered a quality measure. It is a sign of non-covalent bonding between starch granule molecules and one of the factors influencing the α-amylose and amylopectin ratios (Iwe et al., 2016). The swelling capacity of flours is influenced by particle size, species variety, and method of processing or unit operations. (Suresh and Samsher, 2013)

A starch content raises the swelling capacity (index) of foods and flours, particularly those with a high branched amylopectin content. Starch is made up of two chains of glucose units: amylose (linear chain) and amylopectin (branched chain). Granules of starch are very small packets of starch. The amount and proportion of amylose and amylopectin in starch vary depending on the plant source. This explains why the swelling capacities of flours derived from various (plant) sources and species differ.

2.4.5 Foaming Capacity and Foaming Stability

The amount of interfacial area created by whipping a food or flour is used to calculate its foaming capacity. The time required to lose 50% of the liquid or 50% of the volume from the foam is used to calculate foam stability (Mauer, 2003). Protein is the primary cause of foaming. The interfacial film developed by the proteins, which retains the suspension of bubbles and reduces the crystallization rate, is generally responsible for foaming capacity and stability. Extended heat denaturation of proteins reduces their ability to foam.

Foams in foods and other materials commonly disappear over time. Mechanical work is necessary to speed up the surface area of foam. Great foam capacity and stability are desired characteristics for flours used in the production of various baked products, as well as functional agents in many other food applications (El-Adawy, 2001). Protein in the dispersion can reduce surface tension at the air-water interface, and it is frequently due to protein that forms a continuous cohesive thin film around air bubbles in the foam (Kaushal et al., 2012).

The ability of food to stabilize against mechanical and gravitational loads is referred to as foam stability (Fennama 1996). The inverse relationship between foaming capacity and foam stability is significant. Large air bubbles may form around high-foaming-capacity flours, which are ringed by a thinner, less flexible protein film. As a result, these air bubbles may readily collapse, lowering the foam's stability (Jitngarmkusol et al., 2008).

2.5 Crackers

The studies from Sachithra et.al., 2017 define crackers as biscuits with flaky inner walls. Crackers have a moderate amount of sugar, a moderate amount of fat, and a small amount of salt. Crackers are produced in many different shapes such as squares and circles. (fig2.5) (Cauvain, 2016) As a result, crackers can be considered a safe substitute for sweeter foods. Crackers may also be used to use a variety of nutritionally beneficial ingredients. As one of these added ingredients, dietary fiber has gained a number of recognition. High fiber food items are becoming more popular as a means of combating health issues such as asthma, diabetes, and colon cancer.

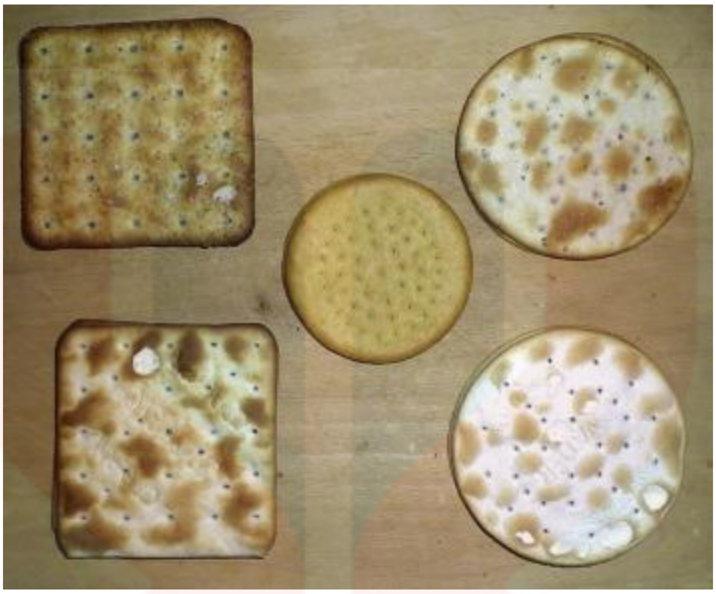

Figure 2.5: Different shapes of crackers (Cauvain, 2016)

2.6 The Functional Properties of Dietary Fiber in Dough.

Definition of dietary fiber currently known as the total of polysaccharide togather with the phenolic polymer lignin that are not digested by the human digestive tract's endogenous secretions (Claye SS et al., 1996). Gómez, Jiménez, Ruiz, & Oliete, 2011 states that changes in physical properties of bakery product will obtained, such as increased, taste firmness of crumb or crumb darkening when addition of large amounts of fiber. The starch-gluten matrix is disrupted when dietary fiber is used instead of flour, and the volume of the biscuit is reduced. By employing a proper proportion of soluble to insoluble fiber fraction and adding or processing the fiber, these negative effects can be mitigated. (Rosell, Santos, & Collar, 2009).

There are a few methods for modifying the properties of dietary fiber to make it more suitable for bread products. The methods employed are chemically, enzymatic processing mechanical and thermal. Certain studies have been undertaken to illustrate the negative impact of large wheat bran size on bread quality due to hydration limitations and its absorption in the structure of gluten viscoelastic (Sanz Penella, Tamayo-Ramos, Sanz, & Haros, 2009).

From the studies of Wen et al., 2017 stated that the distinct physicochemical properties of dietary fibers, as well as their effect on protein and starch in wheat flour. From all functional properties, hydroscopicity has a significant impact on dough characteristics like cohesiveness, hardness, baking characteristics, stability, uniformity and springiness. The porous surface of dietary fibers can serve as active carbon, resulting in high water absorption and thus improved cooking properties of flour based products. Some non-starch polysaccharides, such as phenolic groups, mannan, pectin and xylan have molecular structures with a high number of hydroxyl groups, which allows for greater water inhibition. When a certain amount of dietary fibers is added, a sticky gel network is created by non-covalent interactions such as hydrogen bonds between main chains. This matrix, like a gluten network, will extend the volume, springiness, enhancing uniformity, and resulting in a velvety texture of the resulting bread. (Wen.H et al., 2017)

In cereal goods, the interaction of starches, dietary fibers and proteins can influence texture properties, and studies have revealed a vulnerable fiber-starch-protein network structure. This structure can arise in the presence of dietary fibers, particularly if the addition is at a low level, retaining more water and suppressing excessive starch diffusion and expansion. In the presence of dietary fibers, and particularly when the addition is at a low level, this structure can appear, allowing more water to be retained while suppressing excessive starch expansion and diffusion. When the addition exceeds a certain threshold, though this matrix can be readily broken. As a consequence, the gluten network's efficiency could be adversely affected. (Wen et al., 2017)

2.7 Healthy Snack Food Product

Fruits, legumes, berries, nuts, grains, and seeds; their refined equivalents such as, noodles, breakfast cereals, breads, cooked and fermented vegetables and legumes, and juices, and jams; fruit purées, certain spices and herbs are all examples of plant-based foods. Legumes, nuts and cereals are grain foods that are rich in protein, starch, and lipid content, respectively. Plant-based foods include macronutrients like lipids, proteins and carbohydrates, phytonutrients like polyphenols and carotenoids, in addition to fiber and micronutrients like minerals, trace metals, and vitamins,. (Anthony Fardet, 2017)

A studies from Van Buren, L.et.al, 2019 stated that a higher vegetable consumption has been linked to a lower risk of cardiovascular diseases (CVDs), as well as a lower risk of obesity, type 2 diabetes, chronic respiratory diseases, and certain forms of cancer, according to several reports. Vegetables' advantages in preventing non communicable diseases (NCDs) can be explained by their comparatively high content of micronutrients, polyphenols, antioxidant compounds, and fibers, all of which can counteract the biochemical processes that cause CVDs and other NCDs.

Dietary fiber and phytochemicals including tocopherols, polyphenols, carotenoids, ascorbic acid and tocotrienols have been linked to good health and protection against illnesses like cancer, heart disease, and a variety of other degenerative disorders (Ajila et al., 2008). Various edible plants have traditionally been used for appetizing purposes and various therapeutic purposes across the world. Most of these natural ingredients derived from local plants, on the other hand, have had little scientific research done on them, and their dynamic bio-active principles have not been fully explored. It appears to be the case in the presence of dietary fibre in certain natural products.

CHAPTER 3:

RESEARCH METHODOLOGY

3.1 Materials

Baby corn (*Zea mays)* vegetable, wheat flour, rice flour, sugar, butter and milk powder were used in this research.

3.1.1 Equipment and Apparatus

The apparatus that were used in this processing is the food processor to blend all the ingredients. Then sieving technique were used to produce a powdered form of baby corn by using sieving machine. The oven were used to dry the young corn before use.

3.2 Equipment and Apparatus

3.2.1 Experimental Design

This experiment were started with cleaning and drying process of 1 kg of fresh baby corn vegetable. The formulations of baby corn cracker were developed with the different particle size of young corn powder by sieving process. The few experiments were run after the development of the formulations which were proximate analysis to analyze the nutritional value included with fat content, fiber content, protein content, ash content and moisture analysis. On the other hand, physicochemical analysis were done to analyze the determination of physical analysis of the crackers, determination of texture and determination of color using the crackers sample. Furthermore, the functional properties analysis were carried out to compare the baby corn powder with wheat flour and for the crackers sample. The samples were produced from the different particle size of baby corn powder which uses three different mesh size during the sieving process with addition of the ingredient in crackers making.

3.2.2 Baby Corn Collection

5-6kg of the baby corn vegetable were collected from Wet Market Jeli, Kelantan, Malaysia. The baby corn cob were separated from silk and husk. The raw baby corn were cleaned and chopped into smaller size by using chopping board and knife.

3.2.3 Preparation of Dried Baby Corn Powder

The chopped young corn were dried for two days at 55ºC in an oven (Memmert GmbH & Co. KG, Germany). To produce fine young corn powder, the dried samples were ground using an electric grinder (National MX-895M). In this study, the particle size of baby corn flour, were used to perform the procedure to get three formulations for further analysis. (M: 150; 250 and 500-mesh). (Yusraini et al., 2020) By using the sieve machine, dried young corn powders were separated into three different particle sizes. Three different young corn powder sample were kept separately in airtight container.

3.2.4 Preparation of Crackers

Preparation of crackers was conducted following method described by (Yusraini et al., 2020) with slight modification. Seventy grams (70g) of wheat flour, 10g of baby corn flour 5g of rice flour, 30 g of sugar 1 egg and 15g of bicarbonate were sifted together into a large bowl. Butter (50 g) were added and mixed until it formed a uniform paste. Also 40g of milk powder were added and stirred until the dough formed a stiff ball. With the help of a lightly floured board and rolling pin, the dough were roll out until thin sheet is obtained. With cookie cutter dipped in flour, crackers were cut out. These were put on an ungreased baking sheet and pricked with a fork several times around the top. Powder milk were rubbed on top of each cracker. The crackers were baked in a 220°C oven for 15-20 minutes, or until light gold, then it were cooled on a rack and placed airtight in a glass jar at room temperature.

3.2.5 Formulation of Crackers Incorporated with Different Particle Size of Baby Corn Powder

Nutritious crackers developed from *Zea mays* young corn powder were prepared from three different particle sizes. To get the finest formula for the final product physiochemical analysis and determination the functional properties of crackers and baby corn powder were conducted as below.

Table 3.2.5: Formulation of crackers incorporated with different size of baby corn powder.

	Control	Formulation 1 (125)	Formulation 2 (250)	Formulation 3 (500
Baby corn powder	-	70g	70g	70g
Wheat flour	90g	20g	20g	20g
Milk powder	40g	40g	40g	40g
Sugar	30g	30g	30g	30g
Rice flour	5g	5g	5g	5g
Egg	30g	30g	30g	30g
Baking powder	5g	5g	5g	5g
Total	200g			

3.3 Physicochemical Analysis

3.3.1 Physical Analysis of Crackers

The diameter of the crackers was measured by placing six crackers edge to edge on a scale, rotating them 90 degree and measuring the diameter of six crackers (cm) again, and afterwards taking the mean value. The thickness was determined by stacking six crackers on top of each other and calculating the average thickness (cm). The weight of the crackers was calculated as the average of the values of four individual crackers using a digital weighing scale. The spread ratio was computed by dividing the average diameter by the average thickness of the crackers.

3.3.2 Determination of Texture

The quality parameter, Texture Analyser (Stable Micro Systems, UK) is determined to investigate the consumer acceptability of the crackers. The sample were kept on the flat platform of the instrument. Then, subjected to double compression by a cylindrical probe with 5mm diameter. The speed at 10mm/s is set up using 50N load cell and using a double compression of 40% with trigger force of 0.5kg. The firmness or hardness (peak force), toughness (area under the curve) is determined.

3.3.3 Determination of Color

In the food and bioprocess industries, color is an essential quality attribute and it an affects the consumption of consumer choice and preferences. The color intensity of crackers were measured using Konica Miltona Chroma Meter. The sample were placed in a clear glass plate to enable the chroma meter to detect the color intensity. Color analysis of food products has been used as an indirect indicator of other quality attributes, such as taste and pigment contents, as it is faster, quicker and is well compatible with other physicochemical properties (Pathare, Opara, & Al-Said, 2013).

3.4 Functional Properties of Baby Corn Powder (500µm) Comparing with Wheat Flour and the *Zea Mays* Baby Corn Crackers

3.4.1 Water and Oil Absorption Capacity

Sosulski et al. (1976) method was used to calculate the oil and water absorption capacities of crackers sample and flour samples. The 1g sample was blended with 10 mL of distilled water or refined sunflower oil, left at room temperature for 30 minutes, and centrifuged at 2000g for 10 minutes. The absorption capacity of water or oil was expressed as a percentage of oil or water bound per gram of sample.

3.4.2 Bulk Density

The bulk density was calculated using the method mentioned by Okaka and Potter (1977). The 50g of sample was tapped 20-30 times in a 100 ml measuring cylinder. The mass per unit volume of sample was used to calculate the bulk density.

3.4.3 Swelling Capacity

The swelling capacity was measured by the method of Okaka and Potter (1977), with some adjustments. The sample was loaded to the 10 ml mark in a 100 ml measuring cylinder, then water was added to bring the total volume to 50 ml. By inverting the cylinder, the upper section of the measuring cylinder was tightly covered and combined.

After 2 minutes, the suspension was reversed again and allowed to stand for another 30 minutes. After 30 minutes, the sample's volume was measured.

3.4.4 Foaming Capacity and Foaming Stability

With minor adjustments, the foaming capacity and foaming stability were measured as stated by Narayana & Narasinga Rao (1982). In a measuring cylinder, the sample (1.0 g) was placed to 50 ml distilled water at 30°C. To froth the suspension, it was combined and shook for 5 minutes. Foaming capacity was determined by measuring the volume of foam after 30 seconds of whipping. AW: Where, after whipping, before whipping, BW:

To measure foaming stability as a percentage of the initial foam volume, the volume of foam was measured 1 hour after whipping.

$$FC = \frac{\text{Volume of foam (AW)} - \text{Volume of foam (BW)}}{\text{Volume of foam (BW)}} \times 100$$

3.5 Proximate Analysis of Baby Corn Crackers

3.5.1 Determination of Fat Content

Around 2g of powdered crackers sample was placed into extraction thimble along with petroleum ether. Followed by, weight of pre - dried round blotted sample were recorded. Then, a layer of de-fatted cotton was placed on the sample. After that, the sample was insert to extraction unit part until them attached to the magnets. By heating the solvent within the round bottled flask, extraction began in the soxhlet extractor at a rate of 5 or 6 drops per second condensation for roughly 4 hours. This increases the contact time between the sample and the solvent due to gives time for all the fat found in the sample to dissolve. It is important for the sample to be as finely processed as possible in order for the solvent to penetrate the sample thoroughly (B.Min & W.Ellefson, 2010).

As the final stage, the extracted fat together with flask was replaced in oven for 30 minutes at 105^{o}C and the weight were recorded. Then, replaced it again in desiccator for cooled and weighed. The weight was required to ensure there was no further weight loss. From the weight of the content contained in the receiver flask, the fat content was calculated.

ii. Calculation formula

$$\% \text{ Crude fat} = \frac{(W_2 - W_1)}{\text{Sample (g)}} \times 100$$

W_1 = Weight of empty flask

W_2 = Weight of extracted fat and flask

S = Sample

3.5.2 Determination of Fiber

This fiber test run by automated system of fiber analyzer. The fat-free sample from the crude fat determination experiment is the sample used in this experiment to analyze crude fiber. First, 1 gram of celite were added into fritted glass with 1 gram of powdered sample. Then, the sample were inserted into the fiber analyzer device. After that, the system were washed the samples with acid NaOH. Once done the sample were placed into furnace for at least 5 hours 500^{o}C and let it to cool. Then let the residue in desiccator. Finally, the ash residue weighted.

iii. Calculation formula

$$\% \text{ Crude fiber} = \frac{(W_2 - W_1)}{\text{Sample (g)}} \times 100$$

W2 - W1 = Crude fibre

W1 = Weight of sample

W2 = Weight of sample after furnace (ash)

3.5.3 Moisture Content

Moisture content is one of the most crucial quality parameters of food products. This test will perform by Sartorius Moisture Analyzer using a gravimetric approach. Hence, (7g) of powdered crackers were heated for 7 minutes at 180℃, and the reading were recorded in triplicate (n=3) (Hassanein, Prabawati,& Gunawan-Puteri, 2015).

3.5.4 Ash Content

5g Zea Mays baby corn crackers and control crackers were weighed and placed in a clean, dry, and pre-weighted crucible. After that, the samples and crucible were put in muffle furnaces at 550°C for 6 hours. Before being weighed, the samples were kept cool in a desiccator. The ash content for each flour calculated by using this formula:

$$\% \text{ Crude ash} = \frac{(W_2 - W_1)}{w_s\,(g)} \times 100$$

W_1 = weight of dried sample with crucible

W_2 = weight of sample with crucible

w = weight of sample

3.5.5 Protein

According to procedure AOAC method 7.056 (2000) use with some modification, protein content can be determine by using Kjehdahl method. In this study this method, is used to identify the protein content of *Zea Mays* baby corn crackers and control crackers sample. This method compromises 3 steps below:

i. Digestion

A tube was filled with 1*g* of sample, a kjehdal tablet and 1ml of sulphuric acid. The tube was heated at 400^{o}C for 3 hours then cooled at room temperature for 15 minutes.

ii. Distillation

Following digestion, 50ml of 40% sodium hydroxide and 80ml of distilled water were added to the tube. A conical flask was filled with 25ml of 4% boric acid solution and 2-3 drops of methyl red and bromocresol green. The tube will then be linked to one side of the condenser and the conical flask will be linked to the other side. The volumetric flask was constantly heated until the conical flask was loaded.

iii. Titration

The conical flask disconnected and took for titration. It was titrated against solutions containing 0.1 HCL. The pink hue denotes the finishing point.

i) Calculate for N2 Content:

$$\% \text{ of } N_2 = \frac{(\text{mL standard acid - mL blank}) \text{ x N of acid} \times 1.4007}{\text{Weight } (g)}$$

ii) Crude protein = N% × 6.25

CHAPTER 4:

RESULTS AND DISCUSSION

4.1 Weight loss of fresh Baby Corn

Weight loss is important to identify the yield % at the end of experiment. In this experiment initially collected fresh *Zea Mays* Baby corn showed from farm weighed as 5941.14g. While after dehydrator the weighed as 476.74g. Using the formula below to calculate of yield percentage:

$$\text{Yield\%} = \frac{\text{(Fresh baby corn)}}{\text{(Dry weight)}} \times 100$$

Table 4.1: Yield extract from fresh baby corn

Weight of fresh baby corn(g)	Weight of dried baby corn (g)	% Yield
5941.14	476.74	8.024

Yield percentage is vital to identify the amount of end product produced. In addition to do precise costing, yield checking is important. However, for *Zea Mays* Baby corn the yield produced was 8.024%. This indicate that fresh *Zea Mays* Baby corn high moisture. A study by E.Yusraini et al., 2019 reported that normal baby corn contain around 90% moisture content.

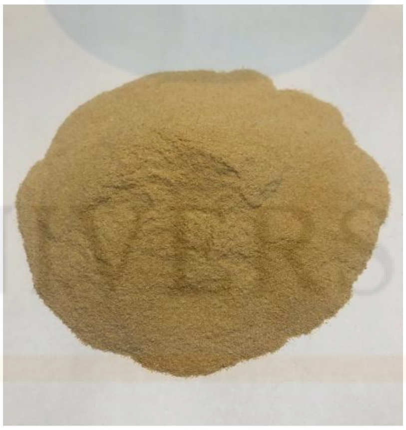

Figure 4.1a: Baby corn powder sieved through 125 µm mesh size.

Figure 4.1b: Baby corn powder sieved through 250 µm mesh size.

Figure 4.1c: Baby corn powder sieved through 500 µm mesh size.

4.2 Development of Crackers from *Zea Mays* Baby Corn

Development of Crackers from *Zea Mays* Baby corn would have rationalized based on proximate analysis. This is to determine the nutritional content in the crackers contained. Apart from that, physicochemical properties based on texture and color to analyze the physical characteristics of the crackers. The baby corn crackers was developed using three different formulations. The formulation created by adding *Zea Mays* Baby corn, wheat flour, milk powder, sugar, baking powder, egg and rice flour

Table 4.2: Amount of ingredients (g) in *Zea Mays* Baby corn crackers

	Control	Formulation1 (125)	Formulation 2 (250)	Formulation 3 (500
Baby corn powder	-	70g	70g	70g
Wheat flour	90g	20g	20g	20g
Milk powder	40g	40g	40g	40g
Sugar	30g	30g	30g	30g
Rice flour	5g	5g	5g	5g
Egg	30g	30g	30g	30g
Baking powder	5g	5g	5g	5g
Total	200g			

Based on Table 4.2 showed the formulation used to derive crackers from *Zea Mays* Baby corn. Therefore, crackers from *Zea Mays* Baby corn maintained in all three formulation. As with the addition milk powder directly results in the changes of Texture, flavor and color. On the addition dairy product to bakery product it will result in browning reaction which affects the flavor, the hardness of the product and stability as well as color. (Gallagher, et al, 2005) However, in formulation 1, formulation 2 and formulation 3 were using different particle size of baby corn powder and it will lead to a huge difference in proximate results and functional properties of baby corn crackers. (Guan, et al., 2020)

Figure 4.2a: The crackers prepared using wheat flour.

Figure 4.2b: The crackers prepared using baby corn flour

sieved through 125µm mesh size.

Figure 4.2c: The crackers prepared using baby corn flour

sieved through 250µm mesh size.

Figure 4.2d: The crackers prepared using baby corn flour sieved through 500µm mesh size.

4.3 Physicochemical Properties of *Zea Mays* Baby Corn Crackers.

4.3.1 Physical Analysis of Crackers

The sample's thickness, diameter, spread ratio, and weight differed considerably ($p<0.05$) (Table 4.3a). The thickness of the crackers grew as the particle size of the baby corn powder in the cracker formulations increased. This might be because the protein content has increased. From the studies of Bala et al., 2015, the diameter or spread ratio is used to examine the effectiveness of flour used in cracker production as well as the cracker's capacity to expand. According to Chauhan, Saxena, & Singh, 2016, the larger the spread ratio of a cracker, the more desired it is. As a consequence, based on the spread ratio, *Zea Mays* baby corn powder crackers may be the most recommended.

Table 4.3a: Physical analysis of *Zea Mays* baby corn crackers

Formulation	Thickness(mm)	Diameter(mm)	Weight(g)	Spread ratio
Control	4±0.4^{a}	42.67b±0.11^{b}	2	10.42±1.1^{a}
Crackers from 125µm baby corn powder	1.48±0.11^{c}	46^{a}	2	31.18±2.16^{c}
Crackers from 250 µm baby corn powder	2.61b±0.12^{b}	46^{a}	2	17.64±0.80^{b}
Crackers from 500µm baby corn powder	2.70b±0.9^{b}	46.3± 0.57^{a}	2	17.17±0.60^{b}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p< 0.05$)

4.3.2 Determination of Texture of *Zea Mays* Baby Corn Crackers

Textural quality [hardness, cohesiveness, gumminess, chewiness, and fracturability] is a critical and preferable quality attribute for crackers. In this studies, the crackers were analyzed all the texture attributes and the result showed below (table 4.3b)

Table 4.3b: Determination of texture of *Zea Mays* baby corn crackers

	Hardness	Cohesiveness	Gumminess	Chewiness	Fracturability
Crackers from wheat flour	6514.46±1061^{b}	1.28c±0.62^{c}	15059±4064^{c}	69.4±3.92^{c}	2610.67±814^{b}
Crackers from 125µm of baby corn powder	6667.67±363^{b}	5.43b±2.02^{b}	62715±5028^{b}	141.93±30.47^{b}	2641.67±30^{b}
Crackers from 250µm of baby corn powder	7782.5±490.97^{a}	0.66c±0.49^{c}	932± 30.20^{c}	15.77±2.05^{c}	5113.67±157^{a}
Crackers from 500µm of baby corn powder	7854±325.43^{a}	14.36a±0.14^{a}	57998±1148^{a}	251.93a±43.25^{a}	5110.33±368^{a}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p < 0.05$)

The particle size of the baby corn powder in the formulation increase as the hardness, which is the peak force needed to break the crackers raises. According to Gómez, J, R. et.al, (2011), the addition of large amounts of fiber results in changes in the physical properties of bakery products such as increased crumb firmness, crumb darkening, or taste. In crackers prepared from 500 µm baby corn powder were higher in the fiber content, the harder the texture of the crackers. (table. 4.6.3)

The other textural factors (cohesiveness, gumminess, and chewiness) were resulted low value by control crackers and crackers made from 125 µm particle sized baby corn powder with a slightly higher value which is can be acceptable by customers. Chewiness is the amount of energy needed to chew solid food until it is able to swallow. It is sometimes calculated as the sum of hardness, cohesiveness, and elasticity (Rosenthal, 1999). This type of crunchy crackers should have less muscle activity while chewing and fewer chews required to prepare the crackers for consuming. Chewiness and cohesiveness had significant positive relationships. The gumminess value of crackers samples ranged from 932±30.20 to 62715b±5028.42 (Table 4.3b). Crackers made from 250 µm particle sized baby corn powder had the lowest value, while crackers made from 125 µm particle sized baby corn powder had the highest value. The gumminess of the crackers, on the other hand, differed significantly ($p<0.05$). Gumminess is defined as the amount of energy required to disintegrate a semisolid food so that it can be swallowed (Trinh & Glasgow, 2012). Gumminess and chewiness may not be mutually exclusive because a crunchy crackers with chewy textural characteristics may adhere to the teeth and become gummy during masticatory with saliva. The crackers made from 125 µm particle sized baby corn powder proved as the value of chewiness increases but the value of gumminess decreases while crackers made from 500 µm particle sized baby corn powder produced vice versa results in this studies.

Fracturability assesses a product's ability to defend and regain its original form. The fracture ability of the crackers samples increased significantly ($p< 0.05$) as the particle size of baby corn powder in the crackers formulation increased. The other parameters are the type, quantity, and protein level of the flour used have all been documented to alter its hardness and other textural aspects. (Gaines, 1993; Pyler, 1982). The results indicated that *Zea Mays* baby corn crackers prepared from 125 µm baby corn powder developed the same results as the control crackers and that it would be suitable for maintaining its shape during transport facilities and would cracking easily when chewed in the mouth (Manley, 2001).

4.3.3 Determination of Color *Zea Mays* Baby Corn Crackers

Color is significant because it might encourage a person's appetite. Because brown pigments arise as caramelization and browning processes occur, it is one of the process control criteria utilized during baking (Pereira, Correia, & Guine, 2013). The findings of the analysis of these crackers are provided below. (Table 4.3c)

Table 4.3c: Determination of color *Zea Mays* baby corn crackers

Formulation	Lightness	Redness	Yellowness
Crackers from wheat flour	74.71±2.78^{a}	2.96± 1.71^{b}	24.39± 0.66^{a}
Crackers from 125µm of baby corn powder	60.69 ±1.8^{c}	11.29± 0.61^{a}	22.15± 0.67^{b}
Crackers from 250µm of baby corn powder	62.79±0.43^{bc}	10.85± 0.82^{a}	24.87± 0.21^{a}
Crackers from 500µm of baby corn powder	66.40±5.84^{b}	9.20± 3.87^{a}	22.77± 0.57^{b}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p < 0.05$)

Positive a* values indicated that redness predominated in the crackers samples. As the particle size of the baby corn powder increased, the color of the crackers transformed to dark brown. This could be due to the oven air velocity ingredient composition, and red pigmentation caused by the non-enzymatic browning, which is dependent on the amount of reducing sugars and amino acids on the surface, baking time and temperature (Pereira et al., 2013). Because the crackers were slightly cooked for a long time, the value of b* in the crackers from 250um was higher.

The 125um powder produced a lighter-colored baby corn cracker. The component that caused the baby corn to become high in lightness and it is because of starch, which was found in the innermost part of the baby corn. Normal corn kernels contained starch in their floury endosperm, which was found inside the kernels and made up the majority of the total endosperm (Yu X, et al., 2015). As a result, the smaller size of baby corn cracker provides more starch than fiber. However, the starch content was not examined in this study.

4.4 Functional Properties of Wheat Flour and Baby Corn Powder (500)

Functional properties of baby corn flour were compared with wheat flour to analyze whether its works functionally in the preparation of bakery goods. The functional properties of the flours that were analyzed are water binding capacity, oil binding capacity, foaming stability and capacity, bulk density and swelling capacity. (Table 4.4)

Table 4.4: Functional properties of wheat flour and baby corn powder (500)

Functional properties	Wheat flour	Baby corn flour
Water absorption capacity *(%)*	83 4.36	706± 47.29
Oil absorption capacity *(%)*	105.5±0.707	151.667± 4.24
Swelling capacity (*ml*)	17.66±2.309	37± 4.36
Bulk density (*ml*)	0.69±0.1	0.79±0.1
Foaming capacity (*ml*)	39.46± 1.03	18.671.15
Foaming stability (*ml*)	8.67±0.58	14.33±1.15

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different (p< 0.05)

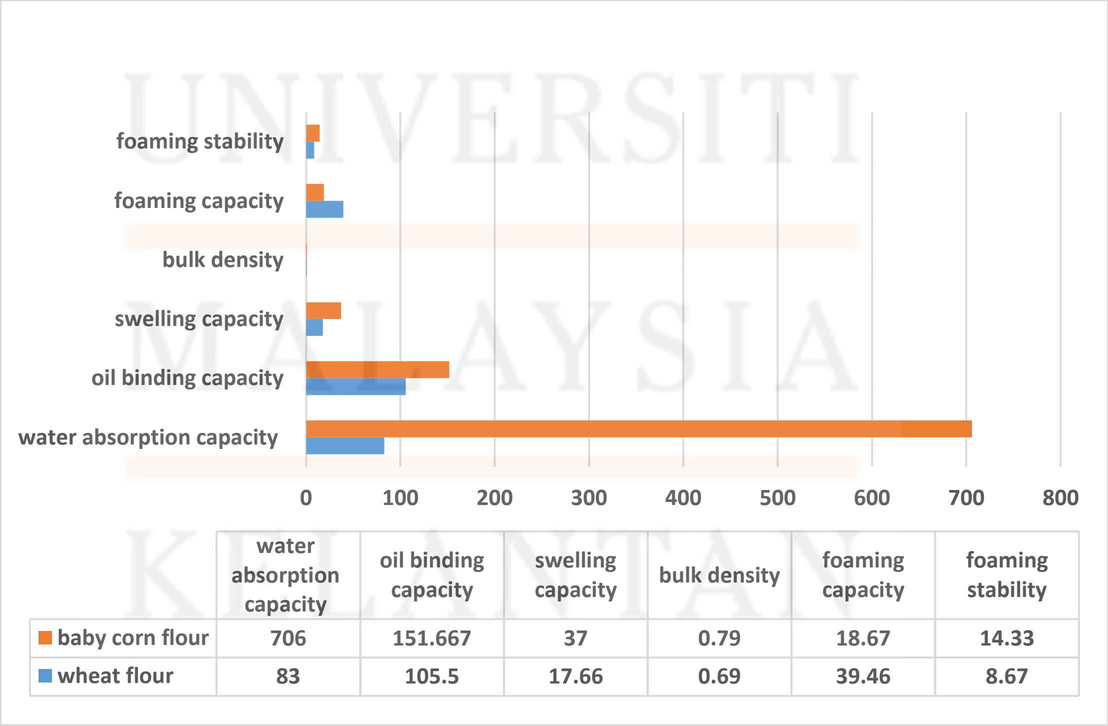

Figure 4.4: Trend of functional properties of baby corn flour and wheat flour.

According to the results table above, the functional properties of baby corn powder increased significantly with the water absorption index, oil absorption index, foaming stability, bulk density, and swelling capacity.

The volume occupied by starch polymers after swelling in excess of water is measured by the water absorption index (Chandra et al. 2015). When compared to wheat flour, baby corn powder has a higher water absorption capacity. When compared to wheat flour, baby corn powder has a higher water absorption capacity. The rising WAC of baby corn powder suggests that it may be used in the formation of certain foods such as bakery products and dough. The increase in WAC has always been associated with an increase in amylose solubility and leaching, as well as a loss in the crystalline structure of starch. Flour with high water absorption may have more soluble components such as polysaccharides.

The OAC content of the flours ranged from 130 to 152 percent. The presence of a high in content of fat in flours may have a negative impact on the OAC of the flours. When compared to other formulations, the 500µm of baby corn powder crackers had a higher percentage of fat content. As a result, amino acid side chain which non polar are presence in the baby corn powder which may bind with the hydrocarbon side chain of the oil among the flours, explaining the possible increase in OAC of 500µm of baby corn powder. Because of these properties, good OAC flours are used as functional ingredients in foods such as bakery products.

When compared to wheat flour, baby corn powder has the highest bulk density. Flour with higher bulk density are suitable for use in food preparation. The lower the bulk density, it would be useful in the formulation of complementary foods (Suresh and Samsher, 2013). Starch is the primary structural and bulking agent in many food products such as bread and biscuits. The swelling power of baby corn powder was high. The starch content of the flour increases the swelling capacity of flour, especially those high in branched amylopectin. Because of their lower protein content, flours have a higher swelling power. When compared to control crackers, the content of protein in the baby corn cracker formulation was low.

Excellent stability and capacity of foaming are desired properties for flours used in the production of a variety of bakery items and it also works as functional ingredients in a variety of other food product manufacturing company (El-Adawy, 2001). Wheat flour had a high foaming capacity but a low foaming stability. The baby corn powder produced the vice versa result which is low in foaming capacity and high in foam stability. The primary cause of foaming is protein. The protein content of the control cracker was higher than the baby corn crackers. This demonstrated that a higher protein content results in a higher foaming capacity. There is a significant inversely proportional between foaming capacity and foam stability. This is because large air bubbles can form around high-foaming-capacity flours surrounded by a less flexible aan thinner protein film. As a result, these air bubbles may collapse easily, reducing the stability of foam. (Jitngarmkusol et al., 2008)

4.5 Functional Properties of *Zea Mays* Baby Corn Crackers and Wheat Powder Cracker Sample

Functional properties of food products are physicochemical indicators that determine how proteins, carbohydrates and fat content behave in the creation of food products, as well as consumer properties. Functional properties of crackers prepared from baby corn flour and wheat flour were determined using standard method. The functional properties of the crackers sample that were analyzed in this study are water binding capacity, oil binding capacity, foaming stability and capacity, bulk density and swelling capacity.

Table 4.5 Functional properties of *Zea Mays* Baby Corn Crackers and Wheat Powder Cracker Sample

Functional properties	Control	Formulation 1 (125 µm)	Formulation 2 (250 µm)	Formulation 3 (500 µm)
Water absorption capacity (*%*)	139±3^{b}	157.33±1.527^{a}	145.33±3.055^{b}	144.33±2.08^{b}
Oil absorption capacity (*%*)	162±1^{a}	159.33± 2.31^{a}	158±2.64^{a}	147.33±2.08^{b}
Swelling capacity (*ml*)	12.33±0.58^{c}	15.33±0.58^{a}	14±1^{b}	15.33±0.58^{a}
Bulk density (*ml*)	0.72±0.06^{a}	0.63±0.06^{b}	0.64±0.1^{b}	0.65± 0.1^{b}
Foaming capacity(*ml*)	6.00±1^{a}	3.67±0.58^{b}	5±1^{ab}	6^{a}
Foaming stability(*ml*)	5.33±1.15^{a}	0^{c}	3.33±1.15^{ab}	2^{bc}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p < 0.05$)

	WAC	OAC	swelling capacity	bulk density	foaming capacity	foaming stability
🟫 f3	144.33	147.33	15.33	0.65	6	2
🟩 f2	145.33	158	14	0.64	5	3.33
🟨 f1	157.33	159.33	15.33	0.63	3.67	0
🟧 control	139	162	12.33	0.72	6	5.33

Figure 4.5: The trend of functional properties of three baby corn crackers formulations and control crackers.

The water absorption capacity % of the crackers ranged from 139 to 157.33, as shown in table 4.5. It has been clearly demonstrated that the smaller the particle size of baby corn powder, the greater its ability to absorb water by the crackers sample. The decrease in particle size from 1127 to 550m lead to improved moisture qualities (water holding, retention, and swelling capacity), which might be ascribed to an increase in theoretical surface area and total pore volume, as well as structural modifications.(Raghavendra et al.,2006) Many hydrophilic components found in food, such as , proteins, particularly polar amino acid residues and carbohydrate, particularly polysaccharides with a significant attraction for water molecules (Sreerama et al., 2012), and other hydrophilic ingredients, contribute to high WAC value. Moreover, there was significant difference ($p>0.05$) on the water absorption capacity result (Table 4.5), the value showed that there was an increase of water absorption capacity in the smaller the particle size of the crackers.

The oil absorption capacity of crackers was found to be significant, indicating that there is a difference between crackers made from wheat flour and crackers made from baby corn powder. The oil binding capacity of the control cracker was increased. The control cracker, made of wheat flour, has a greater percentage of protein content. This theory is strongly associated with the percentage of oil absorption capacity in relation to the percentage of protein content (Table 4.6b) According to the studies of Jitngarmkusol et al.,2008, protein referred in which has both hydrophilic and hydrophobic components, affects oil absorption ability. Protein which named as amino acid, its non-polar side chain can interact hydrophobic with lipid hydrocarbon chains. Absorption of oil processes involves in the interaction of capillary between the matrixes of food, allowing the absorbed oil to be maintained. The next phenomenon is that as the particle size of baby corn powder decreased, the oil absorption capacity increased. The ability to absorb oil may be reduced due to the larger particle size. As a result, the smaller particle size of young corn flour increases surface area, which can improve oil absorption. (Raghavendra et al., 2006)

The weight of many particles of flour material divided by the entire volume they fill is termed as bulk density. It's sometimes referred to as apparent density. It is a functional characteristic of flours, fine particles, flaky goods like crackers, and so on. The total volume includes particle volume, internal pore volume, and inter-particle void volume. (Buckman & Brady, 1960). The 500um young corn powder formulated crackers had the highest bulk density of 0.65 g/mL, while the 125um young corn powder formulated crackers had the lowest at 0.63 g/mL. The difference in bulk density was caused by cracker made from 500um particle size baby corn powder, which most likely contained a higher molecular weight in the same volume.

The swelling power of the crackers was in the range of 13 to 15 according to table 4.5. It's apparent that as the particle size of baby corn powder gets smaller, so does its ability to absorb water. Because of the increase in theoretical surface area and total pore volume, as well as structural alteration, the particle size reduction resulted in higher moisture characteristics such moisture retention, water binding and swelling capacity. (Raghavendra et al., 2006)

According to studies Fennama 1996, the amount of interfacial area that a protein can create is referred to as its foam capacity. Foam is a colloidal material made up of many trapped gas bubbles in a solid or liquid. Small air bubbles are surrounded by thin liquid layers. The foam capacity of various crackers samples ranged from 3 to 7 percent. The control cracker with the highest percentage of protein content had the highest foam capacity, followed by the cracker from 500um baby corn powder crackers, then 250um, and finally 125um.

The ability of protein to stabilize against gravitational and mechanical stresses is referred to as foam stability. The foam stability varied between the crackers, ranging from 2% to 6%. Control crackers had the highest FS (5 percent), followed by crackers from 125µm particle size of baby corn powder (3.33 percent), crackers from 500µm particle size of baby corn powder (2 percent) and crackers from 250µm particle size of baby corn powder (0 percent). Foam capacity and foam stability were shown to be inversely related. The formulation from 500µm particle of baby corn powder crackers shows a higher foaming capacity but the lower foaming stability. This is related to large air bubbles might form around high-foaming formulation, which would be encircled by a thinner, less flexible protein layer. Because the air bubbles were simpler to collapse, the foam's stability was reduced. (Jitngarmkusol et al. 2008).

4.6 Proximate Analysis of Crackers from *Zea Mays* Baby Corn.

4.6.1 Fat Content

According to table 4.6.1, the fat content of all four formulations of *Zea Mays* baby corn crackers were tested in furtherance to assess fat content. Fat content analysis was done by the soxhlet method. Soxhlet method has been a common analytical practice and is undoubtedly the most commonly used and accepted method for lipids extraction.

Table 4.6a: Fat content of *Zea Mays* baby corn crackers

	Fat Content%
Crackers from wheat flour	25.48± 2.530[a]
Crackers from 125µm of baby corn powder	4.356± 0.843[c]
Crackers from 250µm of baby corn powder	4.9567±0.05[c]
Crackers from 500µm of baby corn powder	8.83±0.236[b]

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p< 0.05$)

According to Table 4.6a formulation 1 showed the lowest fat content (4.356±0.843^{c}). Baby corn contained 2.13 percent fat respectively in accordance to the study by Hooda, et al, 2013. Therefore, this study also have proved where the percentage of fat in *Zea Mays* baby corn crackers in the range of 4.26 to 8.83 which is lower than the control sample. The fat content of baby corn crackers in this study were increasing as the larger the particle size of baby corn flour used in the making of crackers. This is because the surface area of the larger particle size are sufficient for oil absorption. (Yusraini, E.et al, 2020)

When wheat flour was replaced with baby corn powder, the fat level of the crackers decreases significantly, ranging from 4.26 to 8.83 percent. According to previous studies, the fat content in sorghum crackers enriched with soy was 20.5. (Serrem et al. 2011). The cracker fat content typically varies between 5 and 20%, the fat content in 250µm and 500µm particle sized baby corn powder crackers were slightly higher (Hodge 1986). This is because milk accounted up to 19% of the total components in the *Zea Mays* baby corn crackers recipe. Higher fat amounts in the finished product might be connected with the fact that additional components such as egg, wheat flour, and baby corn powder also contribute to fat content in a modest way. Meanwhile, the fat level can be reduced by increasing baby corn powder usage in bakery goods. This study showed that the fat content of *Zea Mays* baby corn crackers corroborated with the study (Yusraini, E.et al, 2020), and it is also proved that 125µm particle sized *Zea Mays* baby corn powder crackers was recognized as healthy crackers.

4.6.2 Protein Content

In natural raw foods, protein is recognized as the key structural component that also defines their overall food texture. Despite of their source, all proteins are made up of an amino acid chain. The precise order and ratio of amino acids in the series determines the physical properties of a protein, such as molecular size example shape and charge, solubility.

Table 4.6b: Protein content of *Zea Mays* baby corn crackers

	Protein Content%
Crackers from wheat flour	16.93±0.36^{a}
Crackers from 125µm of baby corn powder	14.00±0.72^{b}
Crackers from 250µm of baby corn powder	14.93±0.15^{b}
Crackers from 500µm of baby corn powder	15.56±0.44^{b}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p < 0.05$)

Based on Table 4.6b protein content for formulation 3 have higher compared to other formulations and control. Curic et al. (2002) also reported the same results that particle size lower than 250 µm reduced Gluten (protein) content of wheat flour. According to Majzoobi et al. (2013), excellent quality proteins such as albumin and globulins were damaged owing to particle size reduction. Because decreasing the size of wheat flour reduces the amount of protein in it, it is advised that wheat flour have particle sizes ranging from 450 to 750µm.

Baby corn contained 17.98 percent of protein respectively in accordance to the study by Hooda, et al, 2013. Crackers prepared from 125and 500µm baby corn powder were in the range between 14 to 16 percent and Crackers prepared from 250µm baby corn powder slightly decreased to 9 percent. This is because the baby corn were dried to produce into powder. Therefore, the nutritional quality of baby corn were slightly decreased. (Anis Jauharah, 2014) Numerous crackers on the market use many ingredients to produce protein content quality products, often using synthetic methods to produce it (Saeki, 2000). However, this *Zea Mays* baby corn produce protein by its natural way without adding any synthetic ingredients.

4.6.3 Fiber Content

In cereals, vegetables, fruits, and nuts, dietary fiber is naturally present. Desmedt & Jacobs, (2001) reported that the amount of fiber and its composition varies. There is a type of fiber contained in baby corn is known as beta-glucan, and commonly found in oat products, it is close to the main fiber. For blood sugar and blood cholesterol control, beta-glucan is effective.

. Table 4.6c: Fibre content of *Zea Mays* baby corn crackers

	Fiber Content%
Crackers from wheat flour	9.9 ± 2.17^{bc}
Crackers from 125µm of baby corn powder	8.32 ± 1.04^{c}
Crackers from 250µm of baby corn powder	12.1667 ± 0.43^{ab}
Crackers from 500µm of baby corn powder	14.35 ± 0.842^{a}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p< 0.05$)

Based on Table 4.6c, the total dietary fiber (TDF) content of *Zea Mays* baby corn crackers differed significantly. The TDF was also raised in proportion to the particle size of the baby corn powder. The TDF content increased from 8.32 to 14.35%. Moreover, the control sample were used refined wheat flour is occasionally used during baking. Dietary fiber is abundant in wheat bran, but refined wheat flour goes through a milling process that removes the bran, resulting in a significant loss of dietary fiber and lowering the proportion of TDF content in crackers made from wheat flour. (Jauharah, et.al, 2014)

As a result, our finding suggests that baby corn powder might be used as an alternate solution of food component to boost the overall dietary fiber content of crackers and other baked items. However, in this research, the increase in net dietary fiber of crackers was still less than that of total dietary fiber content of baby corn powder. This might be owing to the effects of baking heat. (Chang et al, 1990).

4.6.4 Moisture Content

The content of moisture refers to the number of water molecules that are combined into a food product. Moisture content can reach into a food product by various ways, may relate to the manufacturing method of the product, to the ambient moisture in the food processing field, to the packaging method of the product, or may relate to the food storage method (Nielsen, 2010).

Table 4.6d: Moisture content of *Zea Mays* baby corn crackers.

	Moisture Content (%)
Crackers from wheat flour	6.19± 0.23^{c}
Crackers from 125µm of baby corn powder	7.95±0.08^{a}
Crackers from 250µm of baby corn powder	7.48±0.02^{b}
Crackers from 500µm of baby corn powder	6.43±0.05^{c}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p< 0.05$)

From the Table 4.6d the content of moisture in the formulation 1 which is high (7.95± 0.01). , Hence, the particle size reduction of dietary fiber, in this case baby corn powder categorized as dietary fiber sources which allows for an increase of water-holding capacity by increasing the degree of surface development (Chen, et al, 2013). In contrast, *Zea Mays* baby corn crackers from 500µm particle size powder possess low moisture content which believed that can prolong the shelf life and proved that this *Zea Mays* baby corn cracker as a good value-added product to the market. (Chen, J., et al, 2013)

4.6.5 Ash Content

Ash refers to inorganic residue that left following removal of water and organic matter by heat in the presence of oxidizing agents (McClements 2003).

Table 4.6e: Ash content of *Zea Mays* baby corn crackers.

	Ash content (%)
Crackers from wheat flour	6.85 ± 0.7^{a}
Crackers from 125µm of baby corn powder	3.20 ± 0.35^{c}
Crackers from 250µm of baby corn powder	3.88 ± 0.32^{c}
Crackers from 500µm of baby corn powder	5.14 ± 0.29^{b}

Note: Values are expressed as mean ± standard deviation (n=3). Mean values with different superscripts are significantly different ($p < 0.05$)

The table 4.6d shown that the ash content of *Zea Mays* baby corn crackers in range 3.2 % to 5.14%. Baby corn contained 7.18 percent of ash content respectively in accordance to the study by Hooda.et al, 2013. Therefore, the dehydration process and the heating process is reason for degradation of ash content of the crackers sample. (Aydin,.et al., 2015)

Total ash in *Zea Mays* baby corn crackers increases significantly as the particle size of baby corn powder increases. As a result, the ash content will represent the overall minerals content; the inorganic materials in crackers. As a result, from a nutritional standpoint, baby corn powder has the potential to increase the mineral content of baked items.

CHAPTER 5:

CONCLUSION

Finally, baby corn powder possesses properties similar to commercial wheat flour, and can be used in the manufacturing of flour. The results of studies are significance difference between the physicochemical properties and functional properties of baby corn crackers with the different particle size of baby corn powder presented. According to the proximate analysis, baby corn powder crackers are an excellent source of energy. In this study, three distinct particle sizes of baby corn powder crackers demonstrate that they have low fat and protein content and high in dietary fiber sources which indicates that it might be a useful source of food for dieters and baby corn powder might be used as an alternate solution of food component to boost the overall dietary fiber content of crackers.. With particle size such as 125µm, 250 µm, and 500 µm of baby corn powder is suitable to use in food production, particularly confectionery and bakery products. Furthermore, the crackers prepared from 500µm of baby corn powder were good in bulk density, foaming capacity and stability. The crackers prepared from 125µm of baby corn powder were proved that were good in oil and water absorption capacity. The functional property of 500µm of baby corn powder were good in every functional properties that were analyzed in this study except foaming capacity.

5.1 Recommendation

Zea Mays baby corn powder may be further analyzed in terms of proximate composition and physicochemical features such as starch content, fiber, protein, and many others in order to generate a flour-like product in the future. Other than that, in this studies there are further analysis carried for the baby corn crackers but due to shortage of time the sensory evaluation does not carried out. More research is needed to optimize the advantages and use of baby corn powder in food manufacturing by adding it to wheat flour. Moreover, the functional properties such as solubility, gelation and emulsion capacity in the baby corn flour need to be analyze in order to support the production of flour that can be beneficial to pastries industries. this study is also can get further to identify that it is a gluten free flour, which could be advantageous in food manufacturing such as cracker making, biscuits, or pasta that does not require gas retention to retain structure. Aside from that, this baby corn flour may be used as an excellent multifunctional flour, allowing consumers to cook their cuisine in a quick and easy manner. . This study suggested that baby corn powder may be produced as instant flour for confectionery, preserving traditional traditions while maintaining taste. In order to entice children, butter or cheese spread can be added to crackers as a snack option.

REFERENCES

A. G. Hogan, G. T. Gillespie, Osman Koçtürk, B. L. O'Dell, Laura M. Flynn, The Percentage of Protein in Corn and its Nutritional Properties, The Journal of Nutrition, Volume 57, Issue 2, October 1955, Pages 225–239, https://doi.org/10.1093/jn/57.2.225

Ahmedna, M., Prinyawiwatkul, W., & Rao, R. M. (1999). Solubilized wheat protein isolate: Functional properties and potential food applications. *Journal of Agricultural and Food Chemistry*, *47*(4), 1340-1345.

Ajila, C. M., Leelavathi, K. U. J. S., & Rao, U. P. (2008). Improvement of dietary fiber content and antioxidant properties in soft dough biscuits with the incorporation of mango peel powder. *Journal of cereal science*, *48*(2), 319-326.

Asaduzzaman, M., Biswas, M., Islam, M. N., Rahman, M. M., Begum, R., & Sarkar, M. A. R. (2014). Variety and N-fertilizer rate influence the growth, yield and yield parameters of baby corn (Zea mays L.). *Journal of Agricultural Science, 6*(3), 11

Aslam, Muhammad & Sohail, Q & Maqbool, Muhammad Amir & Ahmad, S & Shahzad, Rahil. (2017). Combining ability analysis for yield traits in diallel crosses of maize. Journal of Animal and Plant Sciences. 27. 2017-136

Aydin, E., & Gocmen, D. (2015). The influences of drying method and metabisulfite pre-treatment on the color, functional properties and phenolic acids contents and bioaccessibility of pumpkin flour. *LWT-Food Science and Technology*, *60*(1), 385-392.

Bala, A., Gul, K., & Riar, C. S. (2015). Functional and sensory properties of cookies prepared from wheat flour supplemented with cassava and water chestnut flours. *Cogent Food & Agriculture*, *1*(1), 1019815.

Bawa, A. S., & Sidhu, J. S. (2003). Snack Foods| Range on the Market.

Brady, N. C., & Buckman, H. O. (1960). *The nature and properties of soils* (No. 631.4 B7295n Ej. 6 008553). Macmillan,.

Brewer, M. S. (2011). Natural antioxidants: sources, compounds, mechanisms of action, and potential applications. *Comprehensive reviews in food science and food safety, 10*(4), 221-247.

Bourré, L, Frohlich, P, Young, G, et al.,(2019) Influence of particle size on flour and baking properties of yellow pea, navy bean, and red lentil flours. Retrieved from https://doi.org/10.1002/cche.10161

Chauhan, A., Saxena, D. C., & Singh, S. (2016). Physical, textural, and sensory characteristics of wheat and amaranth flour blend cookies. *Cogent Food & Agriculture*, *2*(1), 1125773.

Chang, M. C., & Morris, W. C. (1990). Effect of heat treatments on chemical analysis of dietary fiber. *Journal of Food Science*, *55*(6), 1647-1650.

Chandra, S., Singh, S., & Kumari, D. (2015). Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. *Journal of food science and technology*, *52*(6), 3681-3688.

Chen, J., Gao, D., Yang, L., & Gao, Y. (2013). Effect of microfluidization process on the functional properties of insoluble dietary fiber. Food Research International, 54(2), 1821–1827. doi:10.1016/j. foodres.2013.09.025

Claye, S. S., Idouraine, A., & Weber, C. W. (1996). Extraction and fractionation of insoluble fiber from five fiber sources. *Food chemistry*, *57*(2), 305-310.

Curic, D., Karlovic, D., Tusak, D., Petrovic, B., & Dugum, J. (2001). Gluten as a standard of wheat flour quality. *Food Technology and Biotechnology*, *39*(4), 353-362.

Dass, S., Yadav, V.K., Kwatra, A., Jat, M.L., Rakshit, S., Kaul, J., Parkash, O., Singh, I., Singh, K.P. and Sekhar, J.C. 2008. Baby corn in India. Technical Bulletin, Directorate of Maize Research, Pusa Campus, New Delhi. 6: 1-45.

Desmedt, A., & Jacobs, H. (2001). Soluble fibre. *Guide to functional food ingredients. Food RA Leatherhead Publishing, Surrey, England*, 112-140.

El-Adawy, T. A., & Taha, K. M. (2001). Characteristics and composition of different seed oils and flours. *Food chemistry*, *74*(1), 47-54.

Fardet, A. (2017). New concepts and paradigms for the protective effects of plant-based food components in relation to food complexity. In *Vegetarian and plant-based diets in health and disease prevention* (pp. 293-312). Academic Press

Fennama RO (1996).Food Chemistry (3rd eds).Marcel Dekker Inc. New York, Basel, Hong Kong, pp 36–39.

Gaines, C. S. (1993). Collaborative studies on the baking quality of cookie flour by wire-cut type formulations (AACC methods 10-53 and 10-54). *Cereal foods world*, *38*(1), 26-30.

Gallagher, E., Kenny, S., & Arendt, E. K. (2005). Impact of dairy protein powders on biscuit quality. *European Food Research and Technology*, *221*(3), 237-243

Gómez, M., Jiménez, S., Ruiz, E., & Oliete, B. (2011). Effect of extruded wheat bran on dough rheology and bread quality. *LWT-Food Science and Technology*, *44*(10), 2231-2237.

Guan, E., Yang, Y., Pang, J., Zhang, T., Li, M., & Bian, K. (2020). Ultrafine grinding of wheat flour: Effect of flour/starch granule profiles and particle size distribution on falling number and pasting properties. *Food science & nutrition*, *8*(6), 2581-2587.

Gunawan-Puteri, M. D. P. T., Hassanein, T. R., Prabawati, E. K., Wijaya, C. H., & Mutukumira, A. N. (2015). Sensory characteristics of seasoning powders from overripe tempeh, a solid state fermented soybean. Procedia Chemistry, 14, 263-269.

Han, W., Ma, S., Li, L., Wang, X. X., & Zheng, X. L. (2017). Application and development prospects of dietary fibers in flour products. *Journal of Chemistry*, *2017*.

Hanif, M. U. H. A. M. M. A. D., Khattak, M. K., Ur-Rahman, S. S., Sher, H. A. F. I. Z. U. L. L. A. H., Khan, S. A. Q. I. B., Saeed, M. U. H. A. M. M. A. D., ... & Saqlain, M. U. H. A. M. M. A. D. (2014). Impact of type and particle size on the protein. Sci. Tech. Dev, 33(3), 107-109.

Hodge, D. G. (1986). Fat in baked products. *Nutrition Bulletin*, *11*(3), 153-165.

Hooda, S., & Kawatra, A. (2013). Nutritional evaluation of baby corn (zea mays). *Nutrition & Food Science*.

Jauharah, M. A., Rosli, W. W., & Robert, S. D. (2014). Physicochemical and sensorial evaluation of biscuit and muffin incorporated with young corn powder. *Sains malaysiana*, *43*(1), 45-52.

Jiang, H., Zhang, M., & Adhikari, B. (2013). Fruit and vegetable powders. In *Handbook of food powders* (pp. 532-552). Woodhead Publishing.

Jitngarmkusol, S., Hongsuwankul, J., & Tananuwong, K. (2008). Chemical compositions, functional properties, and microstructure of defatted macadamia flours. *Food chemistry*, *110*(1), 23-30.

Karam, M. C., Petit, J., Zimmer, D., Djantou, E. B., & Scher, J. (2016). Effects of drying and grinding in production of fruit and vegetable powders: A review. *Journal of Food Engineering*, *188*, 32-49.

Kumar, R., Bohra, J. S., Kumawat, N., & Singh, A. K. (2015). Fodder yield, nutrient uptake and quality of baby corn (Zea mays L.) as influenced by NPKS and Zn fertilization1. *Research on Crops*, *16*(2), 243-249.

Lloyd-Williams, F., Mwatsama, M., Ireland, R., & Capewell, S. (2009). Small changes in snacking behaviour: the potential impact on CVD mortality. *Public health nutrition*, *12*(6), 871-876

Majzoobi, M., Farahnaky, A., Nematolahi, Z., MOHAMADI, H. M., & TAGHIPOUR, A. M. (2013). Effect of different levels and particle sizes of wheat bran on the quality of flat bread.

Manley, D. (2001). *Biscuit, cracker and cookie recipes for the food industry*. Elsevier.

Min, D. B., & Ellefson, W. C. (2010). Fat analysis. In *Food analysis* (pp. 117-132). Springer, Boston, MA.

Narayana, K., & Narasinga Rao, M. S. (1982). Functional properties of raw and heat processed winged bean (Psophocarpus tetragonolobus) flour. Journal of food science, 47(5), 1534-1538.

OKAKA, J. C., & POTTER, N. N. (1977). Functional and storage properties of cowpea powder-wheat flour blends in breadmaking. Journal of Food Science, 42(3), 828-833.

Pathare, P. B., Opara, U. L., & Al-Said, F. A. J. (2013). Colour measurement and analysis in fresh and processed foods: a review. Food and bioprocess technology, 6(1), 36-60.

Pandey, A. K., Ved, P., Mani, V. P., & Singh, R. D. (2000). Effect of rate of nitrogen and time of application on yield and economics of babycorn (Zea mays). *Indian Journal of Agronomy*, *45*(2), 338-343.

Pereira, B. L. C., Carneiro, A. D. C. O., Carvalho, A. M. M. L., Colodette, J. L., Oliveira, A. C., & Fontes, M. P. F. (2013). Influence of chemical composition of Eucalyptus wood on gravimetric yield and charcoal properties. *BioResources*, *8*(3), 4574-4592.

Rani, Reena & Sheoran, R & Soni, Pooja. (2019). BABY CORN: A WONDERFUL VEGETABLE.Retrieved from https://www.researchgate.net/publication/332632400

Ravindran, G., & Matia-Merino, L. (2009). Starch–fenugreek (Trigonella foenum-graecum L.) polysaccharide interactions in pure and soup systems. *Food Hydrocolloids*, *23*(3), 1047-1053

Sanz-Penella, J. M., Tamayo-Ramos, J. A., Sanz, Y., & Haros, M. (2009). Phytate reduction in bran-enriched bread by phytase-producing bifidobacteria. Journal of agricultural and food chemistry, 57(21), 10239-10244.

Serrem, C. A., de Kock, H. L., & Taylor, J. R. (2011). Nutritional quality, sensory quality and consumer acceptability of sorghum and bread wheat biscuits fortified with defatted soy flour. *International Journal of Food Science & Technology*, *46*(1), 74-83.

Silky, M. P. G., & Tiwari, A. (2014). Development of high protein biscuits using pigeon pea broken flour. *International Journal of Engineering and Innovative Technology*, *4*, 84-89

Singh, D. P., Bhardwaj, B. L., & Gupta, B. K. (2006). Analysis of variety diallel cross for forage quality traits in maize (Zea mays L.). Crop Improvement, 33, 34-38.

Sosulski, F., Humbert, E. S., Bui, K., & Jones, J. D. (1976). Functional propreties of rapeseed flours, concentrates and isolate. *Journal of Food science*, *41*(6), 1349-1352.

Sreerama, Y. N., Sashikala, V. B., Pratape, V. M., & Singh, V. (2012). Nutrients and antinutrients in cowpea and horse gram flours in comparison to chickpea flour: Evaluation of their flour functionality. *Food Chemistry*, *131*(2), 462-468.

Suresh, C., & Samsher, C. (2013). Assessment of functional properties of different flours. *African journal of agricultural research*, *8*(38), 4849-4852.

Trinh, K. T., & Glasgow, S. (2012, September). On the texture profile analysis test. In *Proceedings of the Chemeca* (pp. 23-26).

Raghavendra, S. N., Swamy, S. R., Rastogi, N. K., Raghavarao, K. S. M. S., Kumar, S., & Tharanathan, R. N. (2006). Grinding characteristics and hydration properties of coconut residue: A source of dietary fiber. Journal of Food Engineering, 72(3), 281-286.

Rosell, C. M., Santos, E., & Collar, C. (2009). Physico-chemical properties of dietary fibers from different sources: A comparative approach. Food Research International, 42(1), 176–184. doi:10.1016/j. foodres.2008.10.003

Rosenthal, A. J. (1999). Relation between instrumental and sensory measures of food texture. *Food texture: Measurement and perception*, 1-17.

Van Buren, L., Grün, C. H., Basendowski, S., Spraul, M., Newson, R., & Eilander, A. (2019). Nutritional quality of dry vegetable soups. *Nutrients*, *11*(6), 1270.

Wan Ishak, Wan Rosli & Jauharah, C.M.Z. & Robert, Daniel & Aziz, A.I.. (2014). Young Corn Ear Enhances Nutritional Composition and Unchanged Physical Properties of Chiffon Cake. APCBEE Procedia. 8. 10.1016/j.apcbee.2014.03.040

Yadav, A. K., & Singh, S. V. (2014). Osmotic dehydration of fruits and vegetables: a review. Journal of food science and technology, 51(9), 1654-1673.

Yusraini, E., & Lubis, N. D. A. (2020, February). Partial properties of young corn flour based on particle size and its effect on texture and sensory acceptability of biscuit. In *IOP Conference Series: Earth and Environmental Science* (Vol. 454, No. 1, p. 012117). IOP Publishing.

Yu, X., Yu, H., Zhang, J., Shao, S., Xiong, F., & Wang, Z. (2015). Endosperm structure and physicochemical properties of starches from normal, waxy, and super-sweet maize. *International Journal of Food Properties*, *18*(12), 2825-2839.

Zielinska, M., Zielinska, D., & Markowski, M. (2018). The effect of microwave-vacuum pretreatment on the drying kinetics, color and the content of bioactive compounds in osmo-microwave-vacuum dried cranberries (Vaccinium macrocarpon). *Food and Bioprocess Technology*, *11*(3), 585-602.

APPENDIX

Physical analysis of crackers

ANOVA physical analysis of crackers

		Sum of Squares	df	Mean Square	F	Sig.
thickness	Between Groups	9.559	3	3.186	66.178	.000
	Within Groups	.385	8	.048		
	Total	9.945	11			
diameter	Between Groups	26.917	3	8.972	21.533	.000
	Within Groups	3.333	8	.417		
	Total	30.250	11			
weight	Between Groups	.000	3	.000	.	.
	Within Groups	.000	8	.000		
	Total	.000	11			
spreadratio	Between Groups	681.415	3	227.138	132.459	.000
	Within Groups	13.718	8	1.715		
	Total	695.133	11			

Post Hoc Test

Multiple Comparisons							
Tukey HSD							
Dependent Variable	(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
thickness	Control	125um	2.520000*	.179165	.000	1.94625	3.09375
		250um	1.390000*	.179165	.000	.81625	1.96375
		500um	1.300000*	.179165	.000	.72625	1.87375
	125um	control	-2.520000*	.179165	.000	-3.09375	-1.94625
		250um	-1.130000*	.179165	.001	-1.70375	-.55625
		500um	-1.220000*	.179165	.001	-1.79375	-.64625
	250um	control	-1.390000*	.179165	.000	-1.96375	-.81625
		125um	1.130000*	.179165	.001	.55625	1.70375
		500um	-.090000	.179165	.956	-.66375	.48375
	500um	control	-1.300000*	.179165	.000	-1.87375	-.72625
		125um	1.220000*	.179165	.001	.64625	1.79375
		250um	.090000	.179165	.956	-.48375	.66375
diameter	Control	125um	-3.33333*	.52705	.001	-5.0211	-1.6455
		250um	-3.33333*	.52705	.001	-5.0211	-1.6455
		500um	-3.66667*	.52705	.001	-5.3545	-1.9789
	125um	control	3.33333*	.52705	.001	1.6455	5.0211
		250um	.00000	.52705	1.000	-1.6878	1.6878
		500um	-.33333	.52705	.919	-2.0211	1.3545

	250um	control	3.33333*	.52705	.001	1.6455	5.0211
		125um	.00000	.52705	1.000	-1.6878	1.6878
		500um	-.33333	.52705	.919	-2.0211	1.3545
	500um	control	3.66667*	.52705	.001	1.9789	5.3545
		125um	.33333	.52705	.919	-1.3545	2.0211
		250um	.33333	.52705	.919	-1.3545	2.0211
spread_ratio	Control	125um	-20.76000*	1.06920	.000	-24.1839	-17.3361
		250um	-7.22000*	1.06920	.001	-10.6439	-3.7961
		500um	-6.74667*	1.06920	.001	-10.1706	-3.3227
	125um	control	20.76000*	1.06920	.000	17.3361	24.1839
		250um	13.54000*	1.06920	.000	10.1161	16.9639
		500um	14.01333*	1.06920	.000	10.5894	17.4373
	250um	control	7.22000*	1.06920	.001	3.7961	10.6439
		125um	-13.54000*	1.06920	.000	-16.9639	-10.1161
		500um	.47333	1.06920	.969	-2.9506	3.8973
	500um	control	6.74667*	1.06920	.001	3.3227	10.1706
		125um	-14.01333*	1.06920	.000	-17.4373	-10.5894
		250um	-.47333	1.06920	.969	-3.8973	2.9506

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

Homogeneous Subsets

Thickness

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
125um	3	1.48000		
250um	3		2.61000	
500um	3		2.70000	
control	3			4.00000
Sig.		1.000	.956	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

spread_ratio

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
control	3	10.4233		
500um	3		17.1700	
250um	3		17.6433	
125um	3			31.1833
Sig.		1.000	.969	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

diameter

Tukey HSD[a]

Sample	N	Subset for alpha = 0.05	
		1	2
Control	3	42.6667	
125um	3		46.0000
250um	3		46.0000
500um	3		46.3333
Sig.		1.000	.919

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Texture analysis of crackers

ANOVA texture analysis of crackers

		Sum of Squares	df	Mean Square	F	Sig.
hardness	Between Groups	11218534.896	3	3739511.632	25.247	.000
	Within Groups	1184920.833	8	148115.104		
	Total	12403455.729	11			
Cohesiveness	Between Groups	336.259	3	112.086	95.263	.000
	Within Groups	9.413	8	1.177		
	Total	345.672	11			
guminess	Between Groups	45351351579.000	3	15117117193.000	338.861	.000
	Within Groups	356892708.667	8	44611588.583		
	Total	45708244287.667	11			
Chewiness	Between Groups	93932.410	3	31310.803	44.427	.000
	Within Groups	5638.182	8	704.773		
	Total	99570.591	11			
fracturabilty	Between Groups	18539560.250	3	6179853.417	29.263	.000
	Within Groups	1689466.667	8	211183.333		
	Total	20229026.917	11			

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
hardness	125 um	250 um	2585.16667*	314.23463	.000	1578.8768	3591.4566
		500 um	613.66667	314.23463	.281	-392.6232	1619.9566
		control	1414.00000*	314.23463	.009	407.7101	2420.2899
	250 um	125 um	-2585.16667*	314.23463	.000	-3591.4566	-1578.8768
		500 um	-1971.50000*	314.23463	.001	-2977.7899	-965.2101
		control	-1171.16667*	314.23463	.024	-2177.4566	-164.8768
	500 um	125 um	-613.66667	314.23463	.281	-1619.9566	392.6232
		250 um	1971.50000*	314.23463	.001	965.2101	2977.7899
		control	800.33333	314.23463	.126	-205.9566	1806.6232
	control	125 um	-1414.00000*	314.23463	.009	-2420.2899	-407.7101
		250 um	1171.16667*	314.23463	.024	164.8768	2177.4566
		500 um	-800.33333	314.23463	.126	-1806.6232	205.9566
cohesiveness	125 um	250 um	4.76667*	.88566	.003	1.9305	7.6029
		500 um	-8.93000*	.88566	.000	-11.7662	-6.0938
		control	3.14333*	.88566	.031	.3071	5.9795
	250 um	125 um	-4.76667*	.88566	.003	-7.6029	-1.9305

		500 um	-13.69667*	.88566	.000	-16.5329	-10.8605
		control	-1.62333	.88566	.326	-4.4595	1.2129
	500 um	125 um	8.93000*	.88566	.000	6.0938	11.7662
		250 um	13.69667*	.88566	.000	10.8605	16.5329
		control	12.07333*	.88566	.000	9.2371	14.9095
	control	125 um	-3.14333*	.88566	.031	-5.9795	-.3071
		250 um	1.62333	.88566	.326	-1.2129	4.4595
		500 um	-12.07333*	.88566	.000	-14.9095	-9.2371
gumminess	125 um	250 um	61783.00000*	5453.53638	.000	44318.8568	79247.1432
		500 um	-95283.66667*	5453.53638	.000	-112747.8098	-77819.5235
		control	47656.00000*	5453.53638	.000	30191.8568	65120.1432
	250 um	125 um	-61783.00000*	5453.53638	.000	-79247.1432	-44318.8568
		500 um	-157066.66667*	5453.53638	.000	-174530.8098	-139602.5235
		control	-14127.00000	5453.53638	.118	-31591.1432	3337.1432
	500 um	125 um	95283.66667*	5453.53638	.000	77819.5235	112747.8098
		250 um	157066.66667*	5453.53638	.000	139602.5235	174530.8098
		control	142939.66667*	5453.53638	.000	125475.5235	160403.8098
	control	125 um	-47656.00000*	5453.53638	.000	-65120.1432	-30191.8568
		250 um	14127.00000	5453.53638	.118	-3337.1432	31591.1432

		500 um	-142939.66667*	5453.53638	.000	-160403.8098	-125475.5235
chewiness	125 um	250 um	126.16000*	21.67599	.002	56.7459	195.5741
		500 um	-110.00000*	21.67599	.004	-179.4141	-40.5859
		control	72.53333*	21.67599	.041	3.1192	141.9475
	250 um	125 um	-126.16000*	21.67599	.002	-195.5741	-56.7459
		500 um	-236.16000*	21.67599	.000	-305.5741	-166.7459
		control	-53.62667	21.67599	.139	-123.0408	15.7875
	500 um	125 um	110.00000*	21.67599	.004	40.5859	179.4141
		250 um	236.16000*	21.67599	.000	166.7459	305.5741
		control	182.53333*	21.67599	.000	113.1192	251.9475
	control	125 um	-72.53333*	21.67599	.041	-141.9475	-3.1192
		250 um	53.62667	21.67599	.139	-15.7875	123.0408
		500 um	-182.53333*	21.67599	.000	-251.9475	-113.1192
fracturabilty	125 um	250 um	-2472.00000*	375.21845	.001	-3673.5816	-1270.4184
		500 um	-2468.66667*	375.21845	.001	-3670.2482	-1267.0851
		Control	31.00000	375.21845	1.000	-1170.5816	1232.5816
	250 um	125 um	2472.00000*	375.21845	.001	1270.4184	3673.5816
		500 um	3.33333	375.21845	1.000	-1198.2482	1204.9149

		control	2503.00000*	375.21845	.001	1301.4184	3704.5816
	500 um	125 um	2468.66667*	375.21845	.001	1267.0851	3670.2482
		250 um	-3.33333	375.21845	1.000	-1204.9149	1198.2482
		Control	2499.66667*	375.21845	.001	1298.0851	3701.2482
	control	125 um	-31.00000	375.21845	1.000	-1232.5816	1170.5816
		250 um	-2503.00000*	375.21845	.001	-3704.5816	-1301.4184
		500 um	-2499.66667*	375.21845	.001	-3701.2482	-1298.0851

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

Homogeneous Subsets

Hardness

Tukey HSD[a]

sample	N	Subset for alpha = 0.05	
		1	2
250um	3		7782.5000
control	3	6253.6667	
500um	3		7854.0000
125um	3	6782.5000	
Sig.		.126	.281

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Cohesiveness

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
250um	3	.6600		
control	3	2.2833		
125um	3		5.4267	
500um	3			14.3567
Sig.		.326	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Guminess

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
250um	3	932.0000		
control	3	15059.0000		
125um	3		62715.0000	
500um	3			157998.6667
Sig.		.118	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Chewiness

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
250um	3	15.7733		
control	3	69.4000		
125um	3		141.9333	
500um	3			251.9333
Sig.		.139	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Color analysis of the crackers

ANOVA color analysis of the crackers						
		Sum of Squares	df	Mean Square	F	Sig.
lightness	Between Groups	346.991	3	115.664	33.201	.000
	Within Groups	27.870	8	3.484		
	Total	374.861	11			
Redness	Between Groups	157.051	3	52.350	51.953	.000
	Within Groups	8.061	8	1.008		
	Total	165.112	11			
yellowness	Between Groups	15.066	3	5.022	15.998	.001
	Within Groups	2.511	8	.314		
	Total	17.577	11			

Post Hoc Tests

Multiple Comparisons
Tukey HSD

Dependent Variable	(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
lightness	control	125um	14.01667*	1.52396	.000	9.1364	18.8969
		250um	11.91667*	1.52396	.000	7.0364	16.7969
		500um	7.29333*	1.52396	.006	2.4131	12.1736
	125um	control	-14.01667*	1.52396	.000	-18.8969	-9.1364
		250um	-2.10000	1.52396	.545	-6.9803	2.7803
		500um	-6.72333*	1.52396	.010	-11.6036	-1.8431
	250um	control	-11.91667*	1.52396	.000	-16.7969	-7.0364
		125um	2.10000	1.52396	.545	-2.7803	6.9803
		500um	-4.62333	1.52396	.063	-9.5036	.2569
	500um	control	-7.29333*	1.52396	.006	-12.1736	-2.4131
		125um	6.72333*	1.52396	.010	1.8431	11.6036
		250um	4.62333	1.52396	.063	-.2569	9.5036
redness	control	125um	-8.33667*	.81961	.000	-10.9614	-5.7120
		250um	-7.89333*	.81961	.000	-10.5180	-5.2686
		500um	-8.74667*	.81961	.000	-11.3714	-6.1220
	125um	control	8.33667*	.81961	.000	5.7120	10.9614
		250um	.44333	.81961	.946	-2.1814	3.0680
		500um	-.41000	.81961	.957	-3.0347	2.2147
	250um	control	7.89333*	.81961	.000	5.2686	10.5180

		125um	-.44333	.81961	.946	-3.0680	2.1814
		500um	-.85333	.81961	.732	-3.4780	1.7714
	500um	control	8.74667*	.81961	.000	6.1220	11.3714
		125um	.41000	.81961	.957	-2.2147	3.0347
		250um	.85333	.81961	.732	-1.7714	3.4780
yellowness	control	125um	2.24333*	.45746	.005	.7784	3.7083
		250um	-.47667	.45746	.731	-1.9416	.9883
		500um	1.62333*	.45746	.031	.1584	3.0883
	125um	control	-2.24333*	.45746	.005	-3.7083	-.7784
		250um	-2.72000*	.45746	.002	-4.1850	-1.2550
		500um	-.62000	.45746	.557	-2.0850	.8450
	250um	control	.47667	.45746	.731	-.9883	1.9416
		125um	2.72000*	.45746	.002	1.2550	4.1850
		500um	2.10000*	.45746	.008	.6350	3.5650
	500um	control	-1.62333*	.45746	.031	-3.0883	-.1584
		125um	.62000	.45746	.557	-.8450	2.0850
		250um	-2.10000*	.45746	.008	-3.5650	-.6350

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

lightness

redness

Tukey HSD[a]				
sample	N	Subset for alpha = 0.05		
		1	2	3
125um	3	60.6933		
250um	3	62.7933	62.7933	
500um	3		67.4167	
control	3			74.7100
Sig.		.545	.063	1.000
Means for groups in homogeneous subsets are displayed.				
a. Uses Harmonic Mean Sample Size = 3.000.				

Tukey HSD[a]			
sample	N	Subset for alpha = 0.05	
		1	2
control	3	2.9567	
250um	3		10.8500
125um	3		11.2933
500um	3		11.7033
Sig.		1.000	.732
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 3.000.			

yellowness			
Tukey HSD[a]			
sample	N	Subset for alpha = 0.05	
		1	2
125um	3	22.1500	
500um	3	22.7700	
Control	3		24.3933
250um	3		24.8700
Sig.		.557	.731
Means for groups in homogeneous subsets are displayed.			
a. Uses Harmonic Mean Sample Size = 3.000.			

Functional Properties Wheat Flour and Baby Corn Powder

ANOVA of wheat flour and baby corn powder

		Sum of Squares	df	Mean Square	F	Sig.
water_binding	Between Groups	582193.500	1	582193.500	516.358	.000
	Within Groups	4510.000	4	1127.500		
	Total	586703.500	5			
oil_binding	Between Groups	3174.000	1	3174.000	60.076	.001
	Within Groups	211.333	4	52.833		
	Total	3385.333	5			
foaming_capacity	Between Groups	648.544	1	648.544	543.959	.000
	Within Groups	4.769	4	1.192		
	Total	653.313	5			
foaming_stability	Between Groups	48.167	1	48.167	57.800	.002
	Within Groups	3.333	4	.833		
	Total	51.500	5			
swelling_capacity	Between Groups	560.667	1	560.667	46.082	.002
	Within Groups	48.667	4	12.167		
	Total	609.333	5			
bulk_density	Between Groups	150.000	1	150.000	150.000	.000
	Within Groups	4.000	4	1.000		
	Total	154.000	5			

Functional Properties of Zea Mays Baby Corn Crackers

ANOVA of functional properties of crackers

		Sum of Squares	df	Mean Square	F	Sig.
water_binding	Between Groups	539.000	3	179.667	28.747	.000
	Within Groups	50.000	8	6.250		
	Total	589.000	11			
oil_binding	Between Groups	373.333	3	124.444	28.176	.000
	Within Groups	35.333	8	4.417		
	Total	408.667	11			
foaming_capacity	Between Groups	11.000	3	3.667	6.286	.017
	Within Groups	4.667	8	.583		
	Total	15.667	11			
foaming_stability	Between Groups	45.333	3	15.111	22.667	.000
	Within Groups	5.333	8	.667		
	Total	50.667	11			
swelling_capacity	Between Groups	18.250	3	6.083	24.333	.000
	Within Groups	2.000	8	.250		
	Total	20.250	11			
bulk_density	Between Groups	156.333	3	52.111	78.167	.000
	Within Groups	5.333	8	.667		
	Total	161.667	11			

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) sample	(J) sample	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
water_binding	control	125um	-6.33333	2.04124	.058	-12.8701	.2034
		250um	-5.33333	2.04124	.115	-11.8701	1.2034
		500um	-18.33333*	2.04124	.000	-24.8701	-11.7966
	125um	control	6.33333	2.04124	.058	-.2034	12.8701
		250um	1.00000	2.04124	.959	-5.5368	7.5368
		500um	-12.00000*	2.04124	.002	-18.5368	-5.4632
	250um	control	5.33333	2.04124	.115	-1.2034	11.8701
		125um	-1.00000	2.04124	.959	-7.5368	5.5368
		500um	-13.00000*	2.04124	.001	-19.5368	-6.4632
	500um	control	18.33333*	2.04124	.000	11.7966	24.8701
		125um	12.00000*	2.04124	.002	5.4632	18.5368
		250um	13.00000*	2.04124	.001	6.4632	19.5368
oil_binding	control	125um	2.66667	1.71594	.453	-2.8284	8.1617
		250um	4.00000	1.71594	.170	-1.4950	9.4950
		500um	14.66667*	1.71594	.000	9.1716	20.1617
	125um	control	-2.66667	1.71594	.453	-8.1617	2.8284
		250um	1.33333	1.71594	.863	-4.1617	6.8284

		500um	12.00000*	1.71594	.001	6.5050	17.4950
	250um	control	-4.00000	1.71594	.170	-9.4950	1.4950
		125um	-1.33333	1.71594	.863	-6.8284	4.1617
		500um	10.66667*	1.71594	.001	5.1716	16.1617
	500um	control	-14.66667*	1.71594	.000	-20.1617	-9.1716
		125um	-12.00000*	1.71594	.001	-17.4950	-6.5050
		250um	-10.66667*	1.71594	.001	-16.1617	-5.1716
foaming_capacity	control	125um	2.33333*	.62361	.024	.3363	4.3304
		250um	1.00000	.62361	.428	-.9970	2.9970
		500um	.00000	.62361	1.000	-1.9970	1.9970
	125um	control	-2.33333*	.62361	.024	-4.3304	-.3363
		250um	-1.33333	.62361	.220	-3.3304	.6637
		500um	-2.33333*	.62361	.024	-4.3304	-.3363
	250um	control	-1.00000	.62361	.428	-2.9970	.9970
		125um	1.33333	.62361	.220	-.6637	3.3304
		500um	-1.00000	.62361	.428	-2.9970	.9970
	500um	control	.00000	.62361	1.000	-1.9970	1.9970
		125um	2.33333*	.62361	.024	.3363	4.3304
		250um	1.00000	.62361	.428	-.9970	2.9970
foaming_stability	control	125um	5.33333*	.66667	.000	3.1984	7.4682
		250um	2.00000	.66667	.067	-.1349	4.1349

		500 um	3.33333*	.66667	.005	1.1984	5.4682
	125 um	control	-5.33333*	.66667	.000	-7.4682	-3.1984
		250 um	-3.33333*	.66667	.005	-5.4682	-1.1984
		500 um	-2.00000	.66667	.067	-4.1349	.1349
	250 um	control	-2.00000	.66667	.067	-4.1349	.1349
		125 um	3.33333*	.66667	.005	1.1984	5.4682
		500 um	1.33333	.66667	.264	-.8016	3.4682
	500 um	control	-3.33333*	.66667	.005	-5.4682	-1.1984
		125 um	2.00000	.66667	.067	-.1349	4.1349
		250 um	-1.33333	.66667	.264	-3.4682	.8016
swelling_capacity	control	125 um	-3.00000*	.40825	.000	-4.3074	-1.6926
		250 um	-1.66667*	.40825	.015	-2.9740	-.3593
		500 um	-3.00000*	.40825	.000	-4.3074	-1.6926
	125 um	control	3.00000*	.40825	.000	1.6926	4.3074
		250 um	1.33333*	.40825	.046	.0260	2.6407
		500 um	.00000	.40825	1.000	-1.3074	1.3074
	250 um	control	1.66667*	.40825	.015	.3593	2.9740
		125 um	-1.33333*	.40825	.046	-2.6407	-.0260
		500 um	-1.33333*	.40825	.046	-2.6407	-.0260
	500 um	control	3.00000*	.40825	.000	1.6926	4.3074
		125 um	.00000	.40825	1.000	-1.3074	1.3074

		250 um	1.33333*	.40825	.046	.0260	2.6407
bulk_density	control	125 um	9.00000*	.66667	.000	6.8651	11.1349
		250 um	8.33333*	.66667	.000	6.1984	10.4682
		500 um	7.33333*	.66667	.000	5.1984	9.4682
	125 um	control	-9.00000*	.66667	.000	-11.1349	-6.8651
		250 um	-.66667	.66667	.754	-2.8016	1.4682
		500 um	-1.66667	.66667	.134	-3.8016	.4682
	250 um	control	-8.33333*	.66667	.000	-10.4682	-6.1984
		125 um	.66667	.66667	.754	-1.4682	2.8016
		500 um	-1.00000	.66667	.480	-3.1349	1.1349
	500 um	control	-7.33333*	.66667	.000	-9.4682	-5.1984
		125 um	1.66667	.66667	.134	-.4682	3.8016
		250 um	1.00000	.66667	.480	-1.1349	3.1349
*. The mean difference is significant at the 0.05 level.							

water_binding

Tukey HSD[a]

Sample	N	Subset for alpha = 0.05	
		1	2
Control	3	139.0000	
250um	3	144.3333	
125um	3	145.3333	
500um	3		157.3333
Sig.		.058	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

oil_binding

Tukey HSD[a]

Sample	N	Subset for alpha = 0.05	
		1	2
500um	3	147.3333	
250um	3		158.0000
125um	3		159.3333
Control	3		162.0000
Sig.		1.000	.170

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

foaming_capacity

Tukey HSD[a]

sample	N	Subset for alpha = 0.05	
		1	2
125um	3	3.6667	
250um	3	5.0000	5.0000
control	3		6.0000
500um	3		6.0000
Sig.		.220	.428

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

foaming_stability

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
125um	3	.0000		
500um	3	2.0000	2.0000	
250um	3		3.3333	3.3333
control	3			5.3333
Sig.		.067	.264	.067

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

swelling_capacity

Tukey HSD[a]

sample	N	Subset for alpha = 0.05		
		1	2	3
control	3	12.3333		
250um	3		14.0000	
125um	3			15.3333
500um	3			15.3333
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

bulk_density

Tukey HSD[a]

sample	N	Subset for alpha = 0.05	
		1	2
125um	3	63.3333	
250um	3	64.0000	
500um	3	65.0000	
control	3		72.3333
Sig.		.134	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Proximate analysis of the crackers

ANOVA OF PROXIMATE ANALYSIS OF THE CRACKERS

		Sum of Squares	df	Mean Square	F	Sig.
Fat_content	Between Groups	884.999	3	295.000	164.520	.000
	Within Groups	14.345	8	1.793		
	Total	899.343	11			
Protein_content	Between Groups	17.532	3	5.844	20.391	.000
	Within Groups	2.293	8	.287		
	Total	19.825	11			
moisture_content	Between Groups	6.317	3	2.106	134.040	.000
	Within Groups	.126	8	.016		
	Total	6.442	11			
ash_content	Between Groups	23.137	3	7.712	38.549	.000
	Within Groups	1.601	8	.200		
	Total	24.737	11			
fiber_content	Between Groups	62.527	3	20.842	12.431	.002
	Within Groups	13.414	8	1.677		
	Total	75.941	11			

Post Hoc Tests

Homogeneous Subset

Fat_content

Tukey HSD^a

Sample	N	Subset for alpha = 0.05		
		1	2	3
125 um	3	4.3567		
250um	3	4.9567		
500 um	3		8.8300	
Control	3			25.4800
Sig.		.944	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Protein_content

Tukey HSD^a

Sample	N	Subset for alpha = 0.05	
		1	2
Control	3	12.3600	
125 um	3		14.6200
250 um	3		14.9333
500 um	3		15.5633
Sig.		1.000	.214

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

moisture_content

Tukey HSD^a

Sample	N	Subset for alpha = 0.05		
		1	2	3
Control	3	6.1900		
500 um	3	6.4367		
250 um	3		7.4800	
125 um	3			7.9500
Sig.		.152	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

fiber_content

Tukey HSD[a]

Sample	N	Subset for alpha = 0.05		
		1	2	3
125 um	3	8.3233		
Control	3	9.9000	9.9000	
250 um	3		12.1667	12.1667
500 um	3			14.3533
Sig.		.485	.219	.242

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

ash_content

Tukey HSD[a]

Sample	N	Subset for alpha = 0.05		
		1	2	3
125 um	3	3.2000		
250 um	3	3.8767		
500 um	3		5.1400	
Control	3			6.8467
Sig.		.318	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.