MORPHOLOGICAL , TEXTURAL AND SENSORY PROPERTY OF BUN FORMULATED WITH DIFFERENT PARTICLE SIZE OF CORNLETTES POWDER

(*Zea mays L.*)

By

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ABSTRAK

Jagung muda atau jagung pra-matang yang merupakan salah satu sayuran kebiasaannya dimakan oleh penduduk di Malaysia mengandungi serat dietari yang tinggi. Sepintas lalu, jagung muda telah diperkenalkan untuk meningkatkan kualiti nutrisi dalam produk berasaskan bakeri. Kajian ini bertujuan untuk mengkaji kesan penambahan serbuk jagung muda yang berbeza-beza saiz partikel (45,125 dan 250 µm) ke atas kualiti roti ban yang mana meliputi ciri-ciri morfologikal, sifat fizikokimia dan tekstur serta penilaian sensori roti ban jagung muda. Pemerhatian mikroskopikal menunjukkkan partikel tepung gandum dan serat dietari yang padat pada skala pembesaran yang tinggi khususnya dalam roti yang mengandungi saiz partikel jagung muda yang lebih besar (250 µm). Tambahan pula, mikro-struktur serat dietari jagung muda dengan partikel minyak jelas kelihatan. Hal ini membuktikan serat dietari fiber jagung muda berkeupayaan untuk menyerap molekul lemak dalam roti ban. Manakala untuk analisis profil tekstur, penurunan kekerasan (1.45 kg kepada 1.32 kg), kejelekitan (1.74 kg kepada 0.98 kg) dan kekunyahan (1.74 kg kepada 0.98 kg) selari dengan penambahan saiz partikel jagung muda (45, 125, 250 µm) juga diperolehi. Dalam penilaian deria, roti ban dirumuskan dengan 250 µm telah disukai oleh ahli panel walaupun tidak ketara dengan rawatan lain. Antara 3 saiz partikel jagung muda yang berbeza-beza, roti ban ditambah dengan 250 µm saiz zarah jagung muda menghasilkan roti ban yang lembut (1.32 kg), kurang kejelekitan (0.98kg) dan kekunyahan (0.98kg) berbanding dengan rawatan lain. Secara ringkas, roti ban yang ditambah dengan 250 µm saiz partikel jagung muda adalah disyorkan dalam penyediaan serat dietari yang tinggi dalam formulasi roti ban dan diterima dari aspek sensori.

MORPHOLOGICAL ,TEXTURAL AND SENSORY PROPERTY OF BUN FORMULATED WITH DIFFERENT PARTICLE SIZE OF CORNLETTES POWDER (Zea mays L.)

ABSTRACT

Cornlettes or immature corn which is one of the commonly consumed vegetable by Malaysian populace contains high dietary fiber in dried form. Presently, cornlettes have been introduced in enhancing nutritional qualities of baked-based products. This study aims to investigate the influence of different particle size (45, 125 and 250 µm) of cornlettes on the quality of bun which covering morphological characterization, physicochemical, textural property and sensory evaluation. Scanning electron microscopical observation showed that at higher magnification, there are compact particles of wheat flour and dietary fibers especially bun formulated with larger particle size of cornlettes. In addition, microstructure of cornlettes with oily particles intact were clearly seen. Dietary fiber of cornlettes was seen able to absorb fat molecules. For texture profile analysis (TPA), as particle size increases (45,125 and 250 µm), the decreasing of hardness (1.45 kg to 1.32 kg), gumminess (1.74 kg to 0.98 kg) and chewiness (1.74 kg to 0.98 kg) compared to control were observed. In sensory evaluation, bun formulated with 250 µm particle size of cornlettes was preferred by sensorial panellists eventhough not significant with other treatments. Among 3 different particle sizes of cornlettes added in bun formulation, bun added with 250 µm particle size of cornlettes resulted as less firmness (1.32 kg), gumminess (0.98kg) and chewiness (0.98kg) compared to other treatments. In brief, bun added with 250 µm particle size of cornlettes is recommended in the preparation of high fibre and palatable bun.

DECLARATION

I hereby declare that the thesis is my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently submitted for any other degree or purposes in Universiti Sains Malaysia or at any other institutions.

I certify that Miss Wan Nur Suriati Husin has carried out her study entitled 'Morphological Characterizations and Physicochemical Property of Bun Formulated With Different Particle Size of Cornlettes (Zea mays L.)' as a final year research project in nutrition under my supervision. She has complied with the ethical standard and regulations in conducting her study and has completed writing her thesis. I am satisfied with her work and have no objection for the thesis to be examined by the appointed examiners by the School of Health Sciences, Universiti Sains Malaysia.

Thank you.

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Assoc. Prof Dr Wan Rosli Wan Ishak

Date:__________________

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LIST OF ABBREVIATIONS

ATPP - Area To Positive Peak

CLP - Cornlettes Powder

IDF - Insoluble Dietary Fiber

NCD - Non Communicable Disease

NSP - Non Starch Polysaccharide

PPF - Peak Positive Force

PS - Particle Size

TPA - Texture Profile Analysis

SDF - Soluble Dietary Fiber

SEM – Scanning Electron Microscopy

USDA- United States Department of Agriculture

WHO - World Health Organisation

CHAPTER 1: INTRODUCTION

1.1 Background of the study

Non-communicable disease (NCD) is a medical condition or disease which by definition is non-infectious and non-transmissible among people (WHO, 2015). NCDs may be chronic diseases of long duration and slow progression, or they may result in more rapid death such as some types of sudden stroke. WHO has classified NCDs as four main types, they are cardiovascular diseases (like heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructed pulmonary disease and asthma) and diabetes. One of risk factor that leads to the prevalence of NCD is unhealthy diet (WHO, 2015) including insufficient dietary fiber intake.

The recommended daily allowance of dietary fiber for adults aged 19-50 is 25 grams for women and 38 grams for men each day (USDA,2011). After age 50, daily fiber needs decrease to 21 grams for women and 30 grams for men. To meet this fiber goal, eating the recommended amount of fruits, vegetables, legumes (beans), and whole grains from MyPlate is an excellent guide.

Dietary fiber is a ubiquitous component of plant foods and includes materials of diverse chemical and morphological structure, resistant to the action of human gastrointestinal enzymes. Within the gastrointestinal tracts, fiber forms a matrix with both fibrous and amorphous characteristics. The physicochemical properties of this matrix determine the homeostatic and therapeutic functions of dietary fiber in human nutrition. Fiber swells within the aqueous medium of the intestinal lumen taking up water and small molecules including fats. Hence this study want to evaluate and confirm that special characteristics in bun making.

Esther *et al.* (2012) introduced that the particle size of chestnut affects the rheology of the gluten free dough. Either smaller or larger particle size of chestnut powder influences the dough development during baking yield better textural property of the bread. From the study of gluten free bread showed that larger particle size gave more high quality bread but this study lack its mechanism which explained the effect of added different particle size of flour can promote high quality bread. Therefore the effect of different particle size of selected plant materials that is cornlettes toward bun making is studied.

The aim of this work is to study the influence of different particle sizes of cornlettes powder in morphological characteristics and physicochemical properties of bun with the intention in improvement the bun quality. One variety of vegetable cornlettes is used to obtain 3 different particle sizes and later it will be added into burger bun making. The burger bun samples are analyzed for physical and texture properties. The microstructure profile of burger bun added with different particle size of cornlettes will also be studied to explain about how the addition of cornlettes powder in different particle sizes can affect the gluten network in bun and relationship with its physicochemical property of bun.

1.2 Problem statement

Low intake of total dietary fiber among men and women globally that can lead to increase the prevalence of non- communicable disease such as cardiovascular disease, cancers, chronic respiratory disease and diabetes. Thus by increasing the dietary fiber intake in baked-based products can increasing the dietary fiber in the society. Besides, there are bakery products on shelf today are not favourable in texture which might be influenced by the ingredients used. Many study has been done to include different plant material in baked based products but it will lead to more harder texture, and loss its value. According to Zhang and his collegues (2005) , they found that particle size of additive ingredients like barley, oat, corn, and other plant based materials have an effect on baking potential and finished product in bakery (Zhang et al., 2005). Particle size of cornlettes can influence the bun quality, hence this information will improve the bun quality.

1.3 Objectives

1.3.1 General Objective

To investigate the effect of different particle size of cornlettes powder in bun quality.

1.3.2 Specific Objectives

1. To investigate morphological profiles of different particle size of cornlettes added in bun.

2. To examine the physical and textural properties of bun added with different particle size of cornlettes.

3. To determine the sensory acceptance of bun formulated with different particle size of cornlettes.

1.4 Justification of the study

Due to insufficient intake of dietary fiber by various communities worldwide, there is significant awareness to increase the intake of dietary fiber in baked-based food items including bun. The usual intake for dietary fibre is low, 16g/day (Timm and Slavin, 2008) while dietary recommended intakes (DRIs) suggested consumption of dietary fiber up to 25 g/day for women and 38g/day for men (Timm and Slavin, 2008). Hence there is an effort to produce innovative food product to optimize the consumption of dietary fiber in everyday life of Malaysian people. Bun is one type of yeast bread that mostly available in the market and by adding 4% the cornlettes powder, it would increase nutritional value such as total dietary fiber (4.85%), moisture (26.0%), fat (4,56%), protein (9.33%) and decrease carbohydrate (59.12%) and ash (0.98%) content significantly (Lim Jing Yi and Wan Rosli, 2013). So the rationale of eating the baked –based yeast breads including burger bun formulated with cornlettes able to enhance the consumption of healthy food. Healthy food is important in offering well balance foods and nutrients for future growth and development of worldwide population.

CHAPTER 2: LITERATURE REVIEW

2.1 Dietary Fiber

Interest in dietary fiber is a consequence of the investigations that dietary fiber contributes positively to the health and quality of life of the consumer. The need for functional foods of plant origin to combat constipation can be traced back to Hippocrates in the 4th century B.C, who commented on the laxative action of the outer layers of cereal grains. A great deal of debate has continued on the definition of dietary fiber over the past years, together with discussions on methods for measuring this dietary fiber. At the 2008 meeting of Codex Committee on Nutrition and Foods for Special Dietary Uses (CCNFSDU) in Cape Town, South Africa , a consensus decision on the definition of dietary fiber was achieved: "Dietary fibre means carbohydrate polymers with ten or more monomeric units, which are not hydrolyzed by the endogenous enzymes in the human small intestine and belong to the following categories: Edible carbohydrate polymers naturally occurring in the food as consumed. Carbohydrate polymers which have been obtained from raw materials by physical, enzymatic or chemical means and which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities. Synthetic carbohydrate polymers which have been shown to have a physiological effect of benefit to health as demonstrated by generally accepted scientific evidence to competent authorities'' (AOAC, 2008). These fiber pass through the small intestine into the large intestine, where they may be partially or completely fermented by gut bacteria. Therefore they are not absorbed into the bloodstreams.

2.2 Classification of dietary fiber

Dietary fibers subgroups are soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Soluble fibers can dissolve in water and also been found in vegetables, fruits, and legumes like dried beans and peas. Soluble fibers can forms a gel when mixed with liquid.

Table 2.1 : Content of total,insoluble and soluble dietary fiber in food source

Food source	Total dietary fiber [% w/w, d b]	Insoluble dietary fiber [% w/w, d b]	Soluble dietary fiber [% w/w, d b]
Cereal sources			
Wheat flour	3.0	1.9	1.1
Corn flour	2.9	2.9	0.0
White rice flour	2.7	–	–
Barley flour	4.8	2.4	2.4
Whole wheat flour	14.2	11.5	2.6
Whole corn flour	12.8	11.7	1.1
Whole oat flour	10.4	–	–
Whole white rice flour	1.3	0.9	0.4
Whole barley flour	15.4	11.5	3.9
Whole sorghum flour	11.8	10.8	1.0
Wheat bran	48.0	45.6	2.4
Corn bran	88.1	86.0	2.1
Oat bran	24.7	13.0	11.7
Rice bran	27.0	24.5	2.5
Barley bran	72.5	69.4	3.1
Vegetable and pulses sources			
Soy bean	16.3	–	–
Soy bran	67.5	60.5	6.9
Sugar beet pulp	72.5	62.2	10.3
Pea hulls	90.6	85.3	5.3
Commercial sources of highly soluble fibers			
Inulin	100	0	100
FOS	100	0	100
Psyllium	87	17	70
Pectins	90-100	0	90-100
Xanthan, guar, tragacanth, acacia gums	80-90	0	80-90

Dietary fiber is most often classified according to its solubility. A wide range of commercial ingredients containing dietary fiber is available. These ingredients differ in their content of dietary fiber and solubility of the fiber. The total dietary fiber content and solubility level of some ingredients used to enrich products with dietary fiber is given in Table 2.1. In general, refined cereal flours contain a low amount of fiber (between 2 and 5%). Whole grain flours contain a higher amount of fiber (between 10 and 15%). The highest quantity of fiber is found in the bran part of cereals (20 - 90%). In cereals, dietary fiber is mostly insoluble except for oat in which about 50% of the fiber is soluble. Hydrocolloids such as inulin, fructooligosaccharide (FOS), pectin or gums are fully soluble.

2.3 Effect of dietary fiber on textural properties

The mechanical properties of puffed products are driven by the continuous phase properties (physicochemical properties and cell wall thickness) and by the dispersed phase characteristics (porosity, cell size and density and distribution). The force necessary to rupture the expanded sample is most often used to characterize its hardness. Insoluble fiber tends to reduce the sectional expansion and increase the density of the extruded cereals. This induces harder structures to break. This was for instance demonstrated by Brennan et al. (2008) who reported an increased breaking force when increasing wheat bran content up to 15% in extruded breakfast cereals. Similar results were reported for wheat bran by Moore et al. (1990) or for wheat fiber by Onwulata et al. (2001) or Yanniotis et al. (2007). Increase in insoluble fiber content also leads to structure with a higher number of small cells. Robin, Dubois, Curti, Schuchmann, and Palzer (2011d) compared extruded wheat flour samples having the same porosity but different bran content. The increase in breaking strength of these samples with bran can be explained by the finer structures obtained when increasing bran content. While Brennan et al. (2008) observed an increase in breaking force when increasing bran content in extruded corn flour they only observed a slight change when adding either inulin or guar gum. The higher expansion volumes and lower density of extruded corn samples obtained with inulin or guar gum can explain these differences.

Soluble dietary fiber provides larger expansion volumes than insoluble fiber. Nevertheless, their price, lower commercial availability and tendency to dissolve in water producing a gummy or slimy product limit their quantity in extruded products (Blake, 2006). The low physicochemical compatibility between insoluble fiber and starch can mostly explain their reduced expansion volumes. This physicochemical compatibility can be improved by reducing the size of the fiber particles and therefore by increasing contact surface with starch. For instance, at the same extrusion conditions and fiber content, decreasing the average particle size of sugar beet fiber from 200 to 10 mm significantly increases the sectional, longitudinal and volumetric expansion volumes of extruded corn meal Lue et al., 2011). The authors formulated two explanations for this effect: 1) the coarse fiber retards the development of air bubbles and the gas pockets breaks down before they have reached their maximum expansion, 2) the fine fiber because of its greater water-binding capacity has more nucleation sites for watervapor to develop as the material exits the die. Reducing the particle size of corn bran from an average size of 250 mm to less than 50 mm (Blake, 2006) or wheat bran from 1500 to 150 mm also significantly increases the sectional expansion of extruded fiber-containing flours. The effect is nevertheless greater at higher at high concentrations (Blake, 2006).

2.4 Effect of particle size on baked based products quality

The particle size distributions of rice flour and milling processes are important in making gluten-free products. The flour properties passed through 80, 120, 160, and 200 (<180, <125, <95, and <75 mm) mesh sieves (Kim and Shin, 2014). The specific volume of rice cupcakes prepared from HP-160 (<75 mm) rice flour presented the highest value (3.43 mL/g) among them. The particle size of rice flour affected the size of air cell and homogeneity of crumbs. The crumb of cupcake with large sized rice flour formed irregular and inhomogeneous air cells, and the size of air cells in the crumb decreased consistently compared to that in the crumb prepared from large sized rice flour. Therefore, it is predicted that smaller particle sized rice flour with high starch fractions could form small sized air cells with increasing compactness in the crumb of rice cupcake after baking. Hardness, springiness, cohesiveness, and chewiness were significantly different ($p < 0.05$) when different PS of rice flours were used. When cupcake was prepared from smaller particle sized rice flour, hardness of cupcake decreased, but springiness and cohesiveness of cup cake from the larger sized rice flour was lower than those of others. Chewiness decreased in the following order: cupcake was made from HP-120 (<125 mm) > HP-160 (<95 mm) > HP-80 (<180 mm) > HP-200 (<75 mm). When the rice flour butter cakes were made using finer particles (less than 120-mesh), the softer and more palatable cakes were obtained. Particle size distributions of rice flours affected the structure of crumbs in appearance, hardness and softness in texture, and overall quality of cupcake.

CHAPTER 3 : METHODOLOGY

3.1 Study Design

There are control and experimental samples. The control sample is the bun without addition of CLP whereas the experimental samples are the bun formulated with different particle size of CLP which replaced 4% wheat flour with CLP. This experimental design compares the scanning electron microscopy observations, TPA property and sensory acceptabililty of bun added with different particle size of CLP. There are 3 independent variables: 45 μm, 125 μm and 250 μm particle size of CLP.

3.2 Sample collection (CLP)

3.2.1 Inclusive and exclusive criteria for cornlettes selection

Inclusive criteria:

a) Cornlettes from the species *Zea mays* L.

b) Cornlettes from immature stage (35 – 45 days of cultivation).

c) Cornlettes purchased in local market, Pasir Mas, Kelantan.

d) Cornlettes free from defects,foreign smells and pesta attached.

Exclusive criteria:

a) Cornlettes from other species.

b) Cornlettes from mature stage (age more than 45 days of cultivation).

c) Cornlettes purchased from other place.

d) Cornlettes with defects, foreign smells and pests attached.

3.2.2 Preparation of cornlettes powder

The vegetable cornlettes are bought from Kampung Sakar Sungai,Pasir Mas district Kelantan,Malaysia. The cornlettes are dehusked manually. The cobs are manually separated from cornsilk and washed under distilled water. The fresh cornlettes are then manually chopped into small pieces next air dried for 12 hours on stainless steel tray with circulating fan. After that, the dehusked cornlettes are oven dried at 55 ^{0} C for 2 days until brownish threads are obtained. The brownish dried cornlettes is ground into powder from using electrical grinder (National Brand, MX-895, Malaysia) and cornlettes powder is sieved by using analytical siever (AS 200,Germany) having diameter of 45 µm, 125 µm,250 µm.

3.3 Recipe for Bun Making using Different Particle size of Cornlettes Powder

The ingredients used in bun preparation are dry yeast ,fresh milk , butter, sugar , salt, egg , water ,wheat flour and cornlettes powder (Lim Jing Yi, 2012). The 3 sample of buns are prepared by using 4% of cornlettes powder when partial replacement with wheat flour at different particle size of cornlettes. One hundred percent of wheat flour (700g) is used as a control.

For making the bun, there are several steps to be followed. Firstly, flour and instant yeast are mixed evenly. Then, the water is stirred into flour mixture and kneaded for 5 minutes. The sugar,salt,egg,butter and milk are stirred in and kneaded until smooth and soft. The dough is rest for 20 minutes. CLP are put in the dough and are rest for 15-25 minutes. The dough is divided each of ot weighed 60 g and let to rest again for 10-15 minutes. The dough is rolled into the shape of bun and put in the pan brushed with butter. The dough will be covered with humid towel and rise in warm place (35^0 C) until it doubled it size, about 1 hour. Finally baked at 150^0C for 15-20 minutes or until done.

Table 3.1 Composition of ingredients used in bun making formulated with different PS of CLP

Ingredients	Control	45 μm PS	125 μm PS	250 μm PS
Wheat flour(g)	700	672	672	672
Cornlettes powder(g)	0	28	28	28
Dry yeast(g)	11	11	11	11
Fresh milk(ml)	35	35	35	35
Butter(g)	70	70	70	70
Sugar(g@Tbs)	100	100	100	100
Salt (g)	5	5	5	5
Egg (g)	45	45	45	45
Water (ml)	400	400	400	400

3.4 Physical Measurement Analysis of CLP Bun

All burger bun samples added with different particle sizes of cornlettes are used to measure the diameter (D) and thickness (T) using a calibrated ruler. Four measurements are made at different sides for thickness of the burger buns and the average measurements (mm) will be noted. Two measurements are made at two different sides for diameter and the average measurement noted.

3.5 Scanning Electron Microscopy Analysis of CLP Bun

The 4 burger bun samples with different level of particle size are cut into smaller cubicle size (4-5mm in diameter) as aluminium stub is so small (less than 1 cm). The samples are then placed on aluminium stub and are coated with 99.99% pure gold by Sputter Coating machine (Leica,SSD 005). The samples on stub surface are coated with a thin layer of gold (less than 30 nm thickness). Then carefully transfer the samples to SEM machine (FER, Netherland, Belanda). The results later are compared among different particle size of cornlettes in bun. The microstructure of bun are noted and interpreted.

3. 6 Texture Profile Analysis of CLP Bun

The texture profile analysis are conducted on the bun samples prepared with different particle size of cornlettes powder. The hardness, cohesiveness, springiness, gumminess and chewiness of the bun samples are analyzed by using special instrument knowns as Texture Profile Analyzer; Texture Analyser TA.XT PLUS (Stable Micro System,Surrey ,UK) that applies mechanical compression on foodstuff and generates adeformation curve on it response (Lim Jing Yi,2012). The texture analyser are equipped with a 36mm radius cylinder probe (P/36). The operating condition include pre-test speed (2.0 mm/s), test speed (2.0mm/s), post test speed (2.0 mm/s) ,trigger force (20g) and distance (10mm) (Artan ,2010). One cubicle slices of bun with 25 mm thickness are with 6.25 compression distance. Three measurements per loaf for a replication are recorded and three replications are done per batch (Lim Jing Yi, 2012).

Table 3.2: Definitions and calculations for all textural parameters

Parameter	Brief definition	Calculations
Hardness (kg)	The force needed to compress the material by a given amount. Abdelghafor (2011) stated that hardness is the peak force during the first compression cycle.	ATPP from the TPA's graph, unit used in kg.
Cohesiveness	Apply which the strength of internal bonds in the sample. Abdelghafor (2011) defined cohesiveness as the ratio of positive force area during second compression to first compression Cohesiveness = Area 2 / Area 1	Area 4:6 / Area 1:3 There are no unit for this parameters
Springiness	Springiness is the elastic recovery that occurs when the compressive force is removed. Abdelghafor (2011) defined springiness as the height that the food recovers during the time that elapses between the end of the first bite and the start of the second bite. Springiness = time difference 4:5 / time difference 1:2	Time difference 4:6/ Time diffrence 1:3. There are no unit for this parameter.
Gumminess(kg)	The energy required to break down a semisolid food ready for swallowing. Abdelghafor (2011) defined as the product of hardness and cohesiveness.	Hardness x cohesiveness Unit used in kg.
Chewiness(kg)	Chewiness is the energy required to chew a solid food into a state for swallowing. Abdelghafor (2011) defined as the product of gumminess and springiness.	Hardness x cohesiveness x springiness Unit used in kg.

Source : A handbook manual of Texture Analyser TA.XTPlus (Stable Micro Systems, Surrey,UK)

3.7 Sensory Evaluation analysis of burger bun

The sensory evaluation of the CLP bun conducted using 30 untrained panelists from students and staff of the School of Health Sciences, Universiti Sains Malaysia. The parameters evaluated by the panelists include color, aroma, softness, elasticity, flavor and overall acceptance. Bun samples evaluated for above mention criterion on a seven-point hedonic scale ranging from 1 (dislike the most) to 7 (like the most).

3.8 Data analysis

Data obtained is statistically analyzed and tested for significance using analysis of variance (ANOVA) and Duncan Multiple Range test by SPSS Predictive Analytic Software Statistic (PASW) version 22.0. results are expressed as mean ± standard deviation. All measurement are carried out in triplicate (n=3) wtih significant level established at $P \leq 0.05$.

CHAPTER 4 : RESULTS

4.1 MORPHOLOGICAL CHARACTERIZATIONS OF CLP BUN AT DIFFERENT MAGNIFICATION

4.1.1 MORPHOLOGICAL CHARACTERIZATIONS AT LOW(200X) MAGNIFICATION

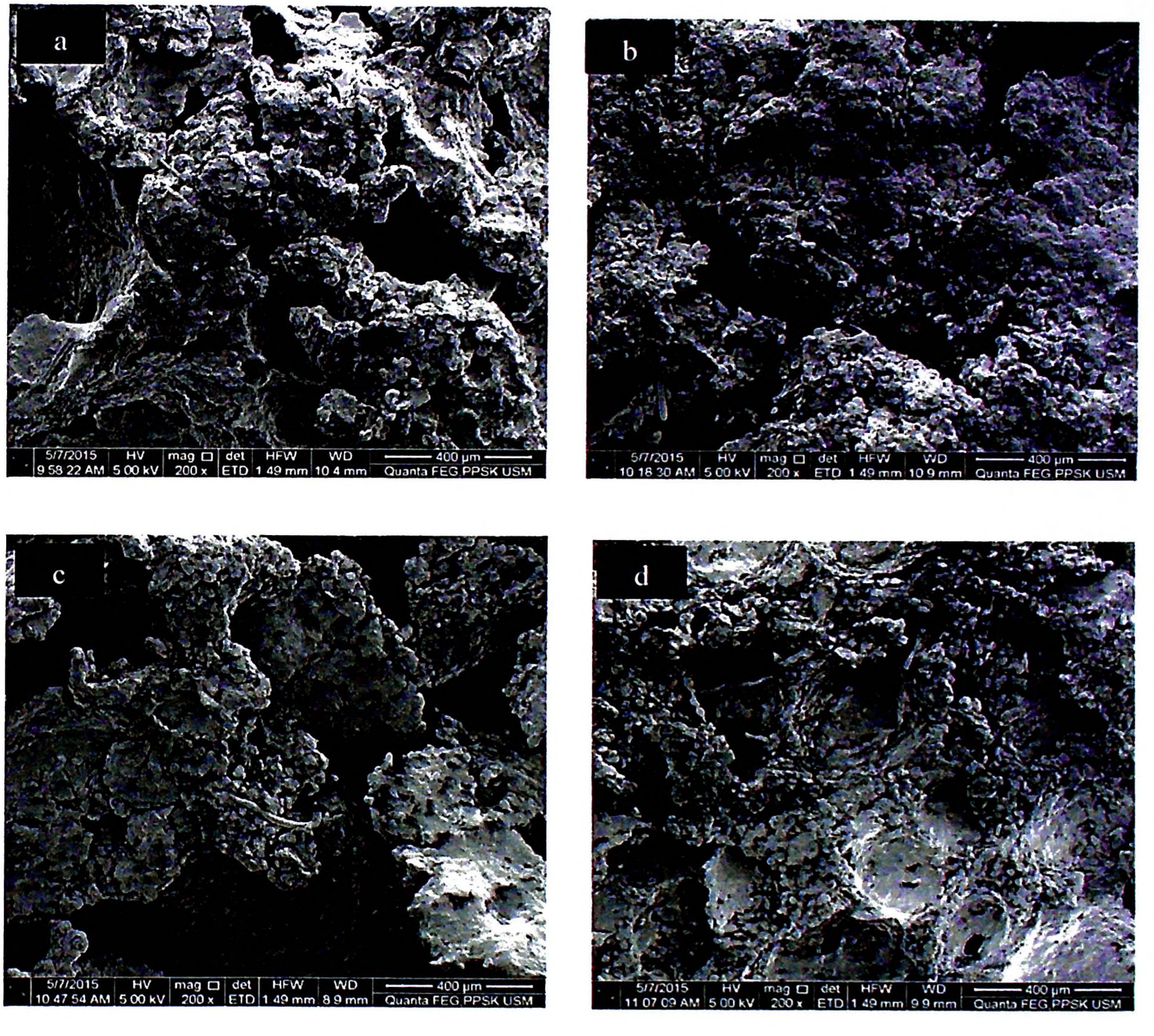

Figure 4.1. Scanning electron photomicrographs at low maginification (200X) of bun added without CLP (4.1a), 45 µm CLP (4.1b), 125µm (4.1c) and 250µm CLP (4.1d). Photomicrograph 1a is a cross sectional control bun shows the starch granules (**X**) which is embedded with other ingredients of bun. **Y** label represents dietary fiber of cornlettes in bun sample.

4.1.2 MORPHOLOGICAL CHARACTERIZATIONS OF BUN SAMPLE AT 500X MAGNIFICATION

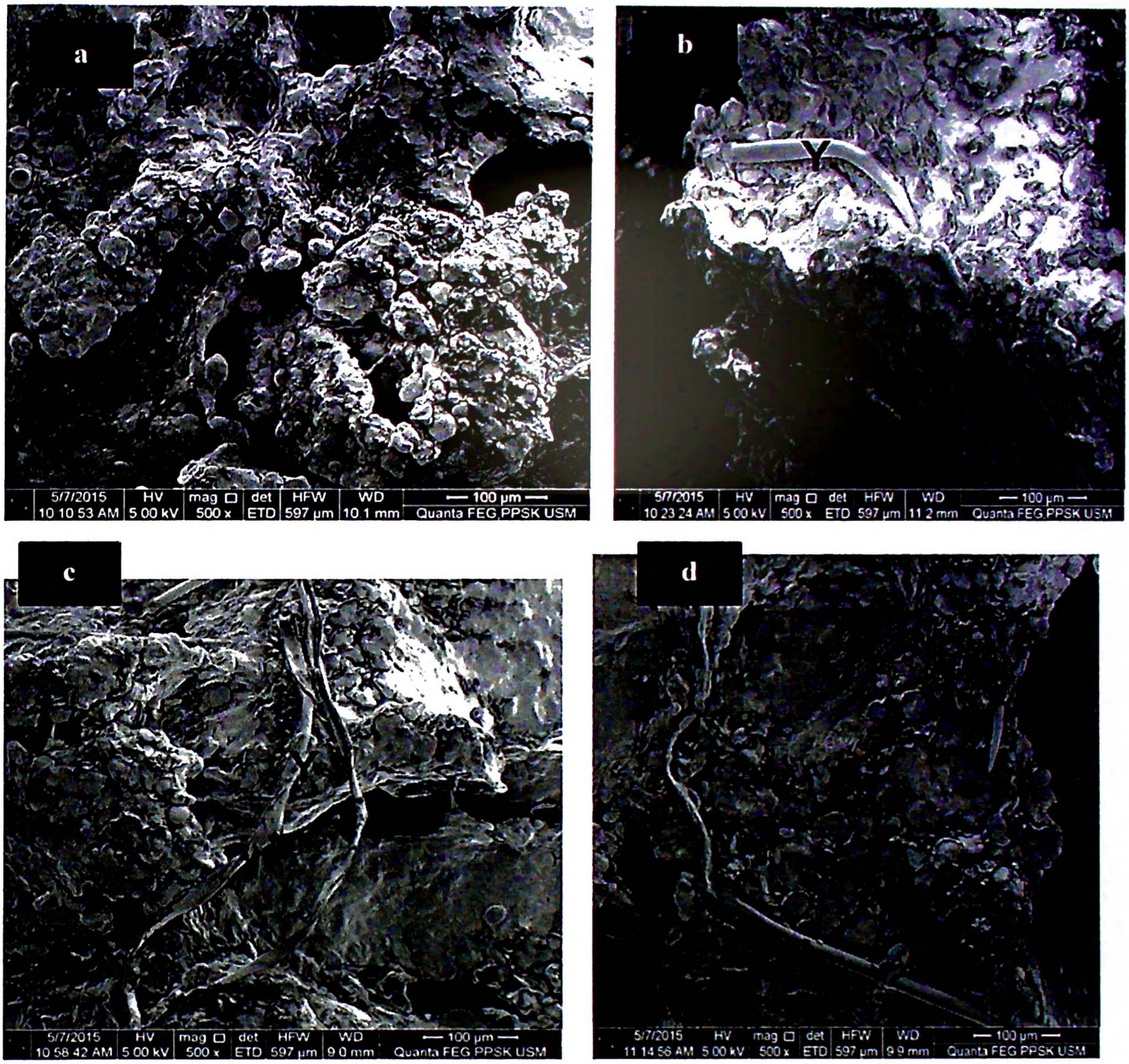

Figure 4.2. Photomigrograph of bun samples at different PS of cornlettes powder, 4.2a: bun sample containing 0% of cornlettes (control), 4.2b: bun containing 4% with 45 µm PS of CLP, bun sample containing 4% with 125 µm PS of CLP, bun sample containing 4% with 250 µm PS of CLP. Photomicrographs of 4.2b, 4.2c and 4.2d show elongated dietary fiber (Y) of cornlettes which were glued together with starch granules (X) and other ingredients.

4.1.3 MORPHOLOGICAL CHARACTERIZATIONS OF BUN SAMPLE AT MODERATELY HIGH MAGNIFICATION (1000X)

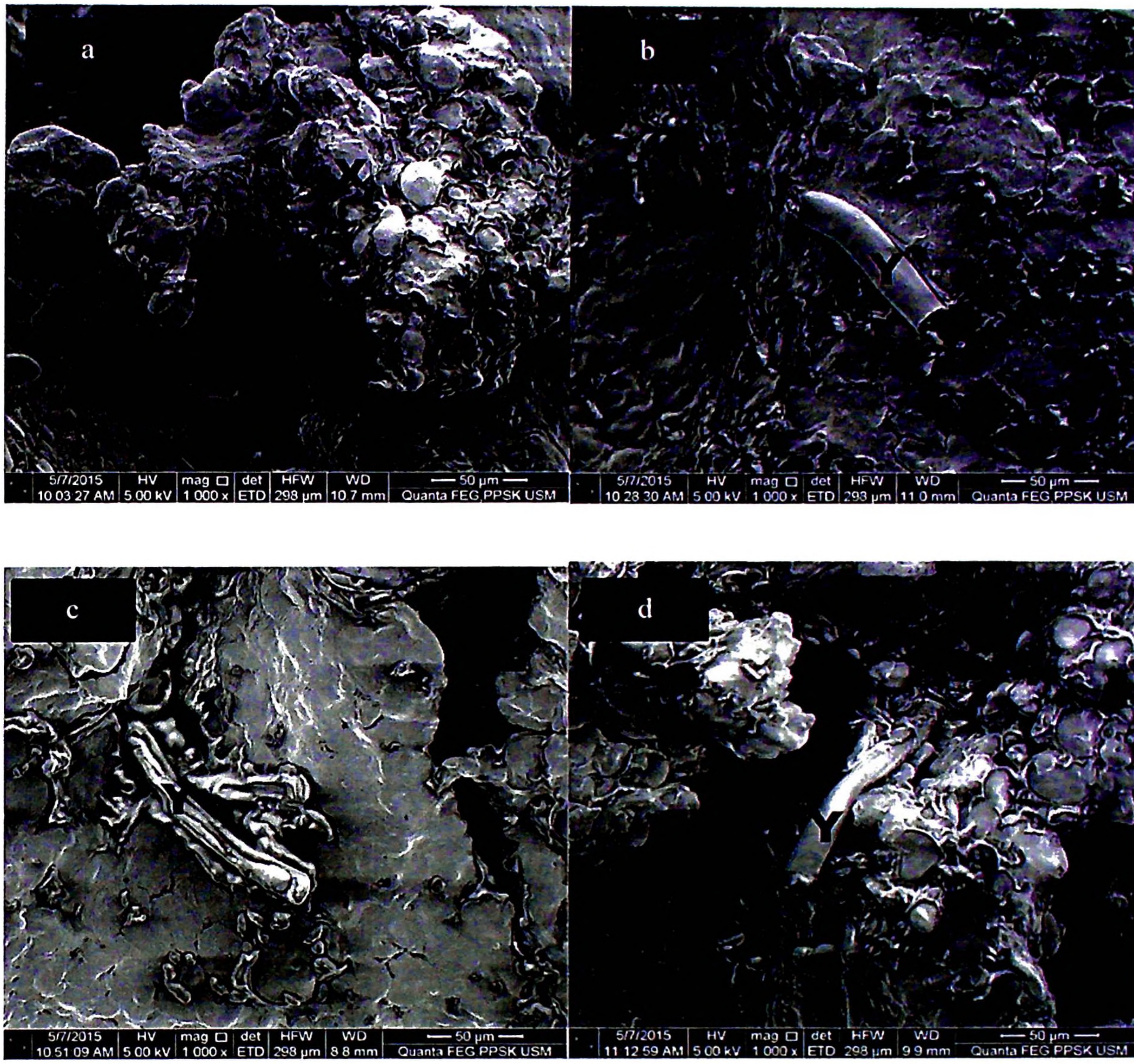

Figure 4.3. Scanning electron photomicrographs at low maginification (1000X) of bun added without CLP (4.3a), 45 µm CLP (4.3b), 125µm (4.3c) and 250µm CLP (4.3d). All CLP-based bun show dominant features of cornlettes fibre which irregularly embedded in the cross sectional surface of bun structure.

4.1.4 MORPHOLOGICAL CHARACTERIZATIONS OF BUN SAMPLE AT HIGH MAGNIFICATION (2000X)

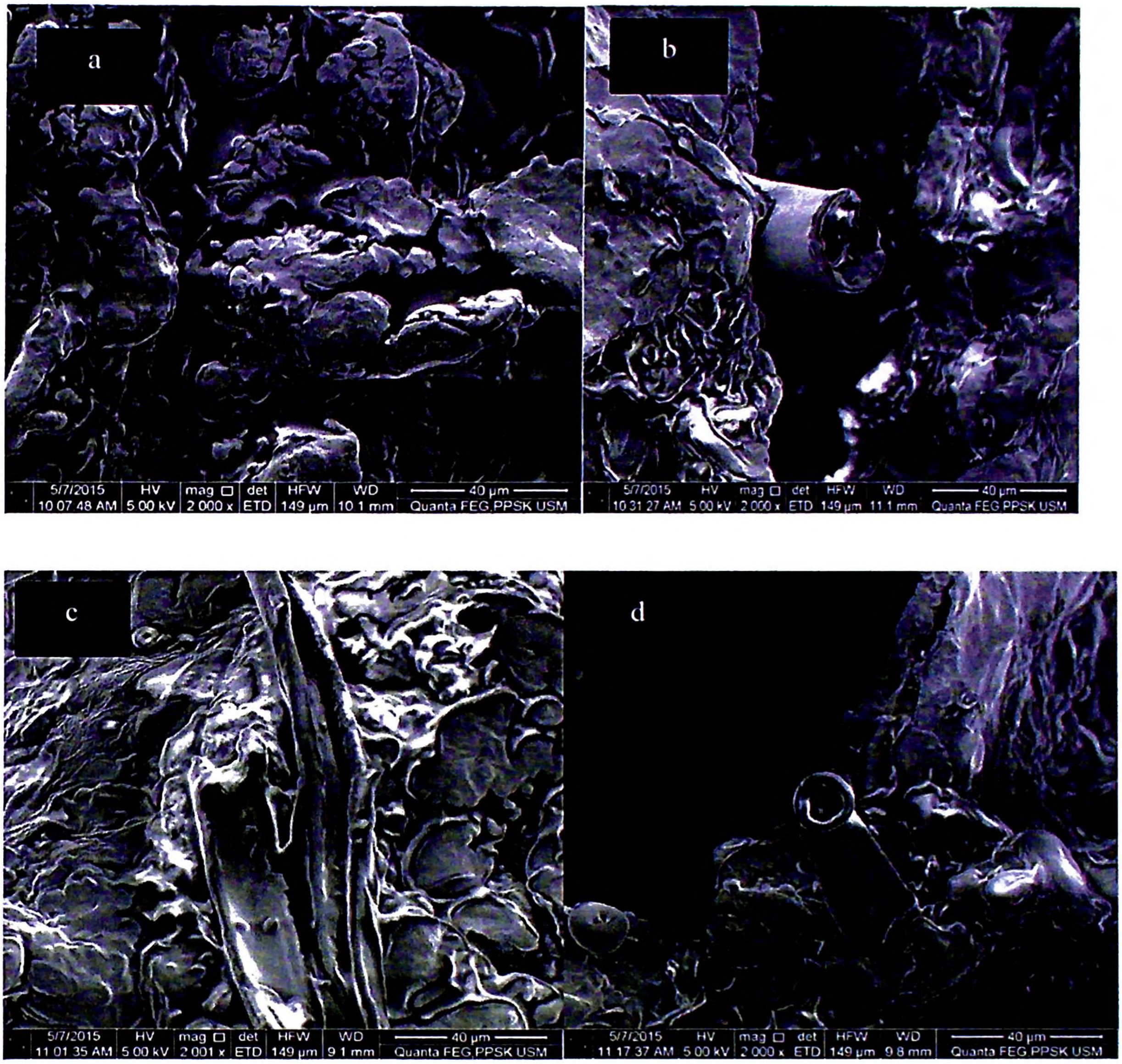

Figure 4.4 Scanning electron photomicrographs at higher maginification (2000X) of bun added without CLP (4.4a), 45 µm CLP (4.4b), 125µm (4.4c) and 250µm CLP (4.4d).

4.2 PHYSICOCHEMICAL PROPERTY OF CLP BUN FORMULATED WITH DIFFERENT PARTICLE SIZE OF CORNLETTES

4.2.1 TEXTURAL PROPERTY OF CLP BUN ADDED WITH DIFFERENT PARTICLE SIZE OF CORNLETTES

The TPA has been extensively used in bakery technology to inspect and quality checking to improve its texture (Cauvain, 2015). Table 4.1 shows the effects of different PS of CLP in bun textural property compared with control bun. Generally, all textural parameters investigated are influenced by different PS of CLP formulation, except for springiness and cohesiveness.

The hardness of bun decreased proportionaly with the increasing PS of CLP formulated. CLP-based bun recorded hardness ranging from 1.03 kg to 1.45 kg as compared to control, 3.24 kg. For the CLP bun added with different PS of CLP (45,125 and 250 μm), there are no significant different ($P > 0.05$) with 1.45 kg, 1.32 kg and 1.03 kg respectively but differ significantly with control CLP bun ($P < 0.05$) with 3.24 kg. The most hardest among different PS of CLP is CLP bun with 45 μm PS (1.13 kg) but when compared to control CLP bun (1.45 kg) , it is the second most hardest and differ significantly ($P < 0.05$). The less hardest which is softer that in CLP bun with 250 μm (1.03 kg).

Similar trend is also recorded in chewiness value of CLP bun with different PS. Chewiness decreased proportionally with the level of PS formulated, ranging from 1.13 kg to 0.73 kg. For the CLP bun added with different PS of CLP (45,125 and 250 μm), there are no significant different ($P > 0.05$) with 1.13 kg, 0.98 kg and 0.73 kg respectively but differ significantly with control CLP bun (P< 0.05) with 1.74 kg. Control CLP bun recorded the highest value of chewiness (1.74 kg) while CLP bun with 250 µm PS recorded the lowest value of chewiness (0.73 kg). Among the CLP bun with different PS formulation, CLP bun with 45 µm PS is the most chewed and CLP bun with 250 µm PS is the less chewed.

Similar trend is also recorded in gumminess of CLP bun with different PS. Gumminess decreased proportionally with the level of PS formulated, ranging from 1.74 kg to 0.73 kg. For the CLP bun added with different PS of CLP (45,125 and 250 µm), there are no significant different (P> 0.05) with 1.13 kg, 0.98 kg and 0.73 kg respectively but differ significantly with control CLP bun (P< 0.05) with 1.74 kg. Control CLP bun recorded the highest value of gumminess (1.74 kg) while CLP bun with 250 µm PS recorded the lowest value of gumminess (0.73 kg). Among the CLP bun with different PS formulation, CLP bun with 45 µm PS is the most gummy and CLP bun with 250 µm PS is the less gummy.

However, the formulation of different PS in CLP bun did not affect the springiness and cohesiveness attributes of CLP bun. The springiness of control CLP bun and CLP bun added with different PS of CLP 45,125 and 250 µm is 1.00 respectively with no significant different (P> 0.05) existed. In term of cohesiveness, control CLP bun (0.54), 45 µm (0.82), 125 µm (0.75) and 250 µm (0.73) of CLP bun did not show significant different (P> 0.05).

Table 4.1. Textural Properties of Bun Formulated With Different Particle Size of Cornlettes Powder

PS of CLP	Hardness(kg)	Springiness	Cohesiveness	Chewiness(kg)	Gumminess(kg)
Control	3.24 ± 0.86^{b}	1.00 ± 0.00^{a}	0.54 ± 0.02^{a}	1.74 ± 0.50^{b}	1.74 ± 0.50^{b}
45 µm	1.45 ± 0.42^{a}	1.00 ± 0.00^{a}	0.82 ± 0.21^{a}	1.13 ± 0.17^{a}	1.13 ± 0.17^{a}
125 µm	1.32 ± 0.16^{a}	1.00 ± 0.00^{a}	0.75 ± 0.05^{a}	0.98 ± 0.12^{a}	0.98 ± 0.12^{a}
250 µm	1.03 ± 0.21^{a}	1.00 ± 0.00^{a}	0.73 ± 0.23^{a}	0.73 ± 0.13^{a}	0.73 ± 0.13^{a}

* The value is the mean ± standard deviation of triplicates.

$^{a-b}$ Mean values within the same column bearing different superscripts differ significantly ($P<0.05$)

Figure 4.5. Graphical Presentation of Textural Property of Bun Formulated with Different PS of CLP