# Bakery Products supplemented with raw Chia – Part 1

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## Abstract

Bakery products are popularly widespread worldwide and highly appreciated by consumers because of their soft texture and characteristic taste. Chia seeds were added to standard bread, muffins and cookies recipes at 5 % and 10 % substitution levels for flour on a weight for weight basis for comparison with standard products. The bakery products were assessed for their baking loss, specific volume, moisture content, textural properties and crumb pore structure. The storage properties of bread were evaluated for 2 days, muffins for 7 days and cookies for 20 days, at 22 -23 °C. Muffins and cookies baking loss and specific volumes were not affected by chia seeds supplementation. Although baking loss for bread was not significantly different for the three formulations, specific volume was decreased with addition of chia seeds. Incorporation of chia seeds in breads tend to decrease the cell density, but does not affect muffins cell density. The appearance of baked products is influenced by the internal and external features which are crucial quality attributes correlating with product flavour and influences the visual perceptions of consumers and potential purchase of the product. The shelf life and the freshness of the bakery products were assessed as quality criterion based on moisture content and the crumb hardness. Bread hardness, gumminess and cohesiveness were not significantly affected by chia supplementation, but were significantly increased during the 48 hours' storage period. Bread cohesiveness and resilience significantly reduced with storage for the three formulations. Bread springiness of the chia supplemented formulations remained stable, while the control increased significantly in storage. Similar to breads, muffin hardness, gumminess and chewiness were not significantly affected by chia supplementations at 5 % and 10 %, but gradually increased for all the formulations during the seven days' storage. Springiness, cohesiveness and resilience were not significantly different two hours after baking of the three formulations, and during the 7 days storage. Cookies stored for twenty days did not significantly change in moisture content. Finally, the results showed that the storage stability of bakery products was unaffected by the addition of raw chia seeds in the formulation. Chia seeds can be used in bakery products to enhance the nutritional value without detrimentally changing the freshness or storage properties.

## 1. Introduction

Bakery products are popularly widespread worldwide with many years of research on improvement of their quality and palatability. Fortification of bakery products is one of the components of nutrition strategies for correction of micronutrient deficiencies. Although food fortification programs have been highly successful in virtually eliminating micronutrient deficiency diseases in the developed countries, there is widespread micronutrient deficiencies particularly in low and middle-income countries that require large-scale fortification of staple foods (Venkatesh Mannar and Hurrell 2018). In Africa, efforts have been made to promote the use of composite flour from locally grown crops to replace a portion of wheat for use in bread, thereby, decreasing the demand for imported wheat and producing protein-enriched bread (Giami et al. 2001). Studies carried out in Kenya to produce composite flours for production of bread and other baked goods include high protein legumes flours, cassava, potatoes, and cereals like maize have partially replaced wheat flour (Kunyanga and Imunge 2010). Demand for value-added foods with functional ingredients such as natural dietary fibre is progressively increasing among consumers (Roos 2004).

The EU approved the promotion of chia seeds as a novel food component at a level of up to 10 % in bakery products, breakfast cereals, fruits, nuts, and seed mixtures (EC 2013) based on the evaluation of EFSA Panel on Dietetic Products, Nutrition and Allergies (2009). Various studies have been conducted in attempts to use chia seeds (*Salvia hispanica L.*) in fortification of bakery products to improve their nutritional quality (Farrera-Rebollo et al. 2012; Zettel and Hitzmann 2016; Zettel et al. 2015; Bustos et al. 2017; Luna Pizarro et al. 2015). Recently the application range and levels have been increased (Turck et al. 2019).

*Salvia hispanica L.*, is a traditional food in central and southern America, that is widely consumed for its various health benefits especially in maintaining healthy serum lipid level, contributed by phenolic acid, omega-3- and omega-6-oil present in the chia seed (Ayerza and Coates 2011; Ixtaina et al. 2008; Llorent-Martínez et al. 2013; Marineli et al. 2014; Muñoz et al. 2013). In Africa, demand for functional food with multiple health benefits has increased with increasing public health awareness worldwide. Chia seed are known to be protein-rich with good balance of essential amino acids, making it suitable for malnourished children and adults living in rural areas who need better access to protein-rich food supply. Chia being an exotic plant in Africa is being investigated for its viability in different agro ecological zones and effect of agronomical treatments on seed quality. Other ecological zones outside South America are successfully evaluated for chia production (Jamboonsri et al. 2012; Bilalis et al. 2016). Chia seeds are rich in total dietary fibre (18–60 g/100g) including polysaccharides, oligosaccharides, lignin and other associated substances (Reyes-Caudillo et al. 2008), that could be a potential ingredient in health and diet food products such as breads, cookies, powders, nutrition bars among other (Zettel and Hitzmann 2018). Chia seeds form mucilage while hydrated in water with desirable physiochemical properties that could be used as industrial additive (La Salgado-Cruz et al. 2013), especially in baked products to prolong freshness (Zettel et al. 2015). However, the effect of chia seeds or mucilage addition on final quality of baked goods need to be investigated.

The objective of this study was therefore to determine the optimum amounts of chia seeds for substitution into baked products and evaluate their effect on the technological quality of these products. This study considered supplementation of chia seeds in yeast breads, muffins and cookies, because they are the commonly consumed bakery products in Kenya, with muffins and cookies ordinarily made at home.

## 2. Materials and method

### 2.1. Materials

As indicated in Table 1, yeast breads, muffins and cookies containing chia seeds were prepared using standard recipes abbreviated as BS. Prior to selecting these recipes, several products were made and evaluated for physical properties. Pre-experiments were carried out with different proportions of chia seeds with finally opting for 5 % and 10 % flour substitution for all the products, abbreviated as BC1 and BC2 respectively. In brief, less than 5 % was found to have minimal quality effect, while more than 10 % generated a dense dark product.

Commercial wheat flour (type 550: 0.51 %-0.63 % mineral supplements in dry matter, Rettenmeier GmbH und Co. KG, Horb am Neckar, Germany) was used for baking bread, muffins and cookies. Organic black chia seeds (Semear Group S.R.L., a produce of Bolvia, 2017) were used as specified by the manufacturer as follows, moisture 5 % (determined), fat 33.4 g of which saturated fatty acids 3.9 g, carbohydrate 7.9 g of which sugars 0.5 g, protein 22.0 g dietary fibre 28.0 g and salt < 0 g., per 100 g of sample. Although chia seeds contain high fat content, no substitution was done for fat. Other ingredients included palm fat (Daabon Organic Japan Co. Ltd, Tokyo, Japan), tap water, dry yeast (saf-instant, S.I. Lesaffre, Marcq, France), sugar (Südzucker Group, Mannheim, Germany), salt (Südsalz GmbH, Heilbronn. Germany), liquid pasteurized whole

**Table 1: Bread formulations using chia seeds as a substitution for wheat flour.**

| **Ingredient** | **Whole Chia seeds substitution in yeast bread** | | |
|---|---|---|---|
| | **0 % (Control)** | **5 %** | **10 %** |
| **Ingredient** | **BS** | **BC1** | **BC2** |
| Wheat Flour Type 550 | 977.51* | 928.6 | 879.8 |
| Water | 580 | 580 | 580 |
| Salt | 20 | 20 | 20 |
| Sugar | 20 | 20 | 20 |
| Fat | 40 | 40 | 40 |
| Yeast | 10 | 10 | 10 |
| Chia seeds | 0 | 48.9 | 97.8 |
| | **Whole Chia seeds substitution in muffins** | | |
| | **0 % (Control)** | **5 %** | **10 %** |
| **Ingredient** | **BS** | **BC1** | **BC2** |
| Wheat Flour Type 550 | 132* | 125.4 | 118.8 |
| Sugar | 130 | 130 | 130 |
| Egg | 105 | 105 | 105 |
| Sunflower oil | 60 | 60 | 60 |
| Baking powder | 5 | 5 | 5 |
| Milk (Skim 1.5%) | 65 | 65 | 65 |
| Chia seeds ( | 0 | 6.6 | 13.2 |
| | **Whole Chia seeds substitution in cookies** | | |
| | **0 % (Control)** | **5 %** | **10 %** |
| **Ingredient** | **BS** | **BC1** | **BC2** |
| Wheat Flour Type 550 | 219.9* | 208.9 | 197.9 |
| Fat | 90 | 90 | 90 |
| Sugar | 67.5 | 67.5 | 67.5 |
| Water | 33.75 | 33.75 | 33.75 |
| Baking agents | 0.675 | 0.675 | 0.675 |
| Salt | 0.75 | 0.75 | 0.75 |
| Chia seeds | 0 | 11.0 | 22.0 |

*The amount of wheat flour was corrected to 14 % from the determined moisture content of 12.021% .
Apart from wheat flour, the water content and other ingredients for the dough and batter were maintained the same for three recipes.

Source: Mburu, Zettel /Graphic: ct 2020

egg (EIPRO-Vermarktung GmbH & Co. KG Gewerbering, Germany), skim milk (1.5% butter fat)(DMK GmbH Industriestraße, Germany) and baking powder (manufactured for BÄKO-Zentrale Süddeutschland).

All formulations were prepared according to the recipes in Table 1. The three product recipes were made in duplicate.

## 2.2. Preparation of baked products

### 2.2.1. Bread

Bread formulations were done using a straight dough preparing method. All doughs were prepared in a planetary mixer (N50, Hobart GmbH, Offenburg, Germany). The dry ingredients were weighed into a bowl. The water was weighed and transferred to the kneader followed by the other ingredients, mixed for one minute at level 1 of the kneader, followed kneading for 5 minutes at level 2 of the kneader. After kneading the dough was left to rest for 20 min in a plastic bowl in the proofing chamber (Wachtel Stamm Petit Computer Proofing Chamber, Wachtel GmbH & Co., Hilden, Germany) at 32 °C and 80 % relative humidity. After resting, the dough was divided into three pieces of equal weight that can fit into the baking pans; pressed and rounded by hand to have better gluten network formation. The doughs were left to rest for 10 minutes to ensure that the dough will not be tight and rubbery, and will easily go through the shape formation without tearing. The dough pieces were formed in the rolling machine and put into greased toast bread pans, then held in proofing chamber for 50 minutes for the above mentioned conditions. Baking was done in a preheated deck oven (Piccolo I, Wachtel GmbH & Co.) for 30 min at 220 °C with steaming for 10 seconds. After baking the breads were placed on cooling rack for 2 hours to cool.

### 2.2.2. Muffins

Muffins formulations were done according to the method described by Baixauli et al. (2008) with modifications. The liquid pasteurized whole egg and sugar were whipped in a Hobart mixing machine for 2 min at speed 2. Wheat flour with baking powder were added and also whipped for 2 min at speed 2. Oil and milk were finally added and mixed in at speed 2 for 1 minute, then 2 minutes speed 3. The batter was placed manually filled into paper muffin cup (50 mm diameter) each containing 42 g of batter. The batters were baked in a preheated oven deck oven (Piccolo I, Wachtel GmbH & Co.) for 30 min at 190 °C both top and bottom temperatures, followed by cooling for 2 hours. For each baking operation the oven level and trays were always the same. The number of muffins baked were always the same per tray. According to the formulation given in Table 1, each preparation gave 11 muffins (42 g x 11 = 462 g batter), which were prepared twice, on different days.

### 2.2.3. Cookies

Cookies were prepared using a standard recipe (Arbeitsgemeinschaft Getreideforschung e. V., Detmold 2016). The ingredients were weighed into a mixing bowl except wheat flour with baking powder. Water adjustment was done to a temperature range of 20 °C - 22 °C, before adding to the other ingredients. The mixture was premixed in a Hobart mixing machine at level 1 (139 rpm) with a flat stirrer for 2 minutes, obtaining a homogeneous mixture. The dough was separated from the boiler wall with a scrapper. The wheat flour was then added and the mixture kneaded at level 1 for two minute. The dough separated from the boiler wall forming a homogeneous consistency. The dough temperature was maintained below 22 °C to avoid oiling out. The dough was immediately removed from the kneading tub, at a temperature of approximately 24 °C, and packed in plastic bags for intermediate storage at 7 °C. This was done overnight after which the dough was removed from the refrigerator and left on the worktable for 15 minutes, for the temperature to raise to 11 °C - 13 °C.

The dough was flattened slightly by hand and rolled out to 5 mm, using the rolling machine, where the rolling distance was reduced continuously by 3 mm from 25 mm to 5 mm. The dough was double rolled at each rolling distance and rotated for 90 degrees every 9 mm. The flattened dough was cut using a 60 mm diameter cookie cutter for the cookies, and placed on a baking tray lined evenly with baking paper with sufficient distance from each other. To determine the weight of the dough pieces, the empty and filled baking tray were weighed. The dough pieces were baked in a preheated deck oven (Piccolo I, Wachtel GmbH & Co.) for 15 min at 210 °C for the top heat and 190 °C for the bottom heat. After the end of the baking process, cookies were removed from the oven and let to cool for 60 minutes.

## 2.3. Characterization of baked products

### 2.3.1. Baking loss and specific volume

After 2 h cooling at room temperature, the baked products were analysed for mass and baking loss. The baking loss was calculated from the difference percentage of dough or batter mass and baked product mass. The baking loss described the loss of weight caused by the loss of water during the baking process and reflects the water binding or gas holding capacity of the dough or masses.

$$baking\ loss\ [\%] = \frac{(m_{dough} - m_{baked\ product})}{m_{dough}} \cdot 100\ \%$$

The volume of bread and muffins were determined with a volume scanner (Volscan profiler 600; Stable Micro Systems, Surrey, England). For the muffins, the volume of three samples selected at random was determined and calculated to the whole volume. The volume of the cookies was determined approximately by means of a mathematical calculation using the formula for the cylinder volume. For this purpose, the height (h) and the biscuit diameter (d) were determined with a calliper. The height of the biscuits corresponded to ten biscuit parts. The volume yield and specific volume were calculated using the following formula:

$$volume_{cookie} = \pi \cdot r^2 \cdot h$$

$$volume\ yield = \frac{volume_{cookie}[cm^3 or\ mL]}{m_{dough}[g]}$$

$$specific\ volume\ \left[\frac{mL}{g}\right] = \frac{volume_{cookie}[cm^3 or\ mL]}{m_{cookie}[g]}$$

### 2.3.2. Products structure

Photograph images of the bread and muffin crust were taken before the bread was sliced, and bread crumb of three slices were taken before the TPA measurements. The muffins were cut in cross sections to expose the crumb, and the halves used for TPA and pores measurements. The bread slices and muffin halves were scanned for pore structure that compares pore size distributions.

### 2.3.3. Moisture content

Moisture determination was done using a calibrated infrared moisture analyser KERN ML S-D (KERN & SOHN GmbH Balingen – Germany). Moisture contents of bread and muffins were determined from the central crumb in three replicates for each tested condition. Moisture content of cookies was determined by crushing a representative sample to get a homogenous mass.

### 2.3.4. Texture Analysis

Textural properties of bread and muffins crumbs after baking and during storage were determined with texture profile analyser - TPA (TA-XT2; Stable Micro Systems, Surrey, England) with a modified AACC method (74-09), using measurement geometry of standard 25-mm-diameter probe and 5 kg load cell and the force deformation curve was recorded. Before the test was conducted on the sample, the machine was calibrated for load and distance. Three slices (25 mm thickness) were taken from the center of each bread loaf compressed twice to 40 % deformation with 15 s rest with a test speed of 1.7 mm/s. Two bite tests where used that mimics the mouths' biting activity allowing analysis of how bread responds when chewed. Multiple textures were obtained in one test and calculated by the automatic integrated macro functions. From the resulting stress-strain curve, the hardness, gumminess, chewiness, resilience, springiness and cohesiveness of breads were calculated. The hardness measured the peak force that occurred during the first compression. Cohesiveness was the area of work during the second compression divided by the area of work during the first compression while springiness measured the distance of the detected height during the second compression divided by the original compression distance. Gumminess was the product of hardness and cohesiveness, while chewiness measured product of hardness, cohesiveness and elasticity. Resilience measures how well the bread crumbs fights to regain its original height, and was measured on the withdrawal of the first penetration, before the waiting period started. Cookies resistance to bending or snapping was determined with texture profile analyser - TPA (TA-XT2; Stable Micro Systems, Surrey, England),using measurement geometry of standard P/75 aluminium, 75 mm diameter, the test speed of 0.5 mm/s and 5 kg load cell and heavy duty platform. Samples were always placed with the top upward and three replicates were carried out for each cookie formulation. The Texture Analyzer determined the first bite force of the product by performing single-cycle measurements. Hardness value was obtained from the maximum force applied to bend the cookies, while fracturability value was observed from the distance at the point of break.

### 2.3.5. Storage studies

For each bread variation, the slices were stored in low density poly propylene bags of 160 gauge and store in the cellar, 22°C - 23°C for quality monitoring after one day and two days. Muffins per variation were also stored in low density poly propylene bags of 160 gauge at the cellar, 22 °C – 23 °C for quality monitoring after 2 days, 5 days and 7 days, because normally they have a longer shelf life and freshness. Similar storage for cookies per formulation was done for quality monitoring after 5 days, 10 days, 15 days and 20 days of storage. The stored samples were evaluated for moisture content and texture.

### 2.4. Statistical analysis

All products were baked twice on different days with the similar settings and controls. All the results were reported as the means of triplicate analyses. The quality characteristics were analysed using analysis of variance (ANOVA) to determine the effect of chia seeds in the baked products and significance difference among the means. The results of the measurements were compared within and between the groups and interaction among the three replications. Least significant differences were calculated by Fisher's test and the significance was determined at $p< 0.05$.

## 3. Results and Discussion

### 3.1. Baking Tests

### 3.1.1. Baking loss and specific volumes

Table 2 shows the baking loss and specific volume of the baked products. There were no significance differences in baking loss and specific volume for muffins and cookies formulations. Although baking loss for bread was not significantly different ($p<0.05$) for the three formulations, specific volume was decreased with addition of chia seeds. This may be explained by the high fibre content of the chia seeds (28 g/100 g sample), that increases the total dietary fibre in dough leading to higher water absorption and smaller extensibility effect. The effect was experienced in bread due to large amount of dough used in comparison to muffins and cookies. Coelho and Salas-Mellado (2015) observed similar results of decreasing specific volumes for bread made with addition of chia flour and reduced hydrogenated vegetable fat. On the contrary, Zettel et al. (2015), observed higher volume yields for breads with added chia gel, which included more water. Although bread is sold by weight, consumers prefer well-risen and well-shaped loaves. Breads volume is determined by gas formation contributed by varying factors like fermentation of sugars by yeast and retention of gas affected by fibre content of the dough. Van Hung et al. (2007) recommended increase of amount of water added to the dough that can solve the negative effect of flour substitution and gluten dilution on the loaf volume. Research on bread supplementation with other grains such as barley, cellulose and oat caused a reduction in loaves volume as reported by Hamed et al. (2015). Partial substitution of wheat with other grains dilutes the gluten and subsequently, affect the optimum gluten matrix formation during the kneading, fermentation and baking processes (Feili et al. 2013).

**Table 2: Baking loss and specific volumes of bread, muffins and cookies**

| **Bread** | **BS** | **BC1** | **BC2** |
|---|---|---|---|
| Baking Loss (%) | 10.18±0.7a | 10.0±1.0a | 9.5±0.7a |
| Specific volume (ml/g) | 1.41±0.03b | 1.38±0.0a | 1.32±0.05a |
| **Muffins** | **BS** | **BC1** | **BC2** |
| Baking Loss (%) | 13.2±0.2a | 12.7±0.8a | 12.5±0.4a |
| Specific volume (ml/g) | 0.73±0.11a | 0.74±0.04a | 0.74±0.07a |
| **Cookies** | **BS** | **BC1** | **BC2** |
| Baking Loss (%) | 12.87±0.04a | 12.73±1.17a | 12.92±0.66a |
| Specific volume (ml/g) | 0.06±0.01a | 0.05±0.02a | 0.05±0.02a |

Abbreviations: BC, Standard Bread, BS1, Bread supplemented with 5 % chia seeds, BS2, Bread supplemented with 10 % chia seeds

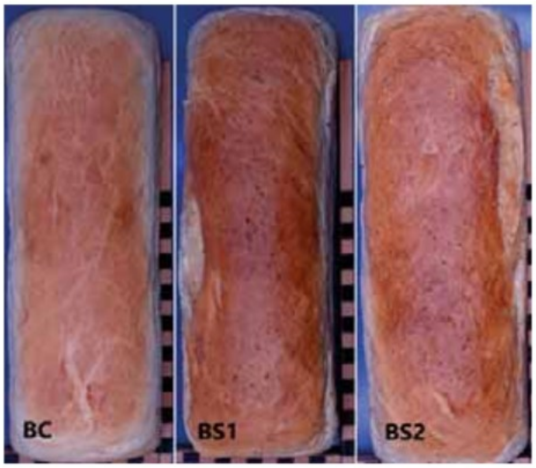
Means followed by the same lowercase letters in the same row did not differ significantly ($p < 0.05$).

Source: Mburu, Zettel /Graphic: ct 2020

Addition of chia seeds in bread has been reported to reduce its volume, increase hardness and present darker crumbs in some research on bread fortification (Steffolani et al. 2015; Luna Pizarro et al. 2013; Steffolani et al. 2014; Luna Pizarro et al. 2015). Also reported by Wang et al. (2002), the fiber addition in bread causes a reduction of loaf volume. Other authors in similar studies (Steffolani et al. 2014; Luna Pizarro et al. 2013; Coelho and Salas-Mellado 2015) reported similar correlation.

### 3.1.2. Product cellular structures

Baked products have a heterogeneous cellular structure, which affects the mechanical behaviour of the crumbs. According to the loaf pictures presented in Figure 1, the loaves have visible oven springs that are more pronounced in bread supplemented with chia seeds, which is an indication of more expansion of the loaf in the oven. Oven spring is a good indicator of better crumb of bread because more oven spring means a light and airy interior and little oven spring indicates a dense, compact crumb. All the three bread formulations had good crumb as can be seen in Figure 2. However, the 10 % supplemented bread crumb was darker in colour. Muffin images are presented in Figure 3. The chia supplemented products had visible chia seeds on the crust which makes them, more attractive. All muffin preparations achieved similar product sizes, which is attributed to the same specific volume as earlier reported. The photography of products for the three cookies formulations is presented in Figure 4. The chia-supplemented cookies had visible seeds on with 10 % formulations showing more seeds as compared to 5 % formulation. Consumer acceptability of the products need to be evaluated in subsequent studies. The sugar used as an ingredient in formulation of cookies, contribute to surface colour through caramelization as well as flavour and sweetness. It also acts as a hardening agent creating a firm texture. The cookies in Figure 4 were smooth with less cracks, an indication of less recrystallization of sugar at the surface of the cookies. The cookies were crispy after baking and cooling, due to low moisture content which was 2.33 %, 2.46 % and 2.26 % for the control, 5 % and 10 % formulations respectively.

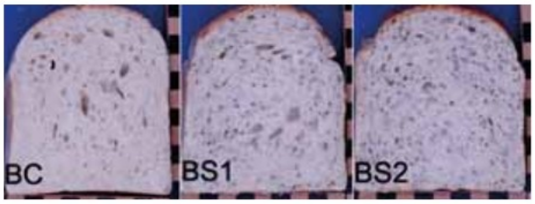


Source: Mburu, Zettel 2020

**Fig. 1:** Photograph images of the bread surfaces (Abbreviations: BC, Standard Bread, BS1, Bread supplemented with 5 % chia seeds, BS2, Bread supplemented with 10 % chia seeds)

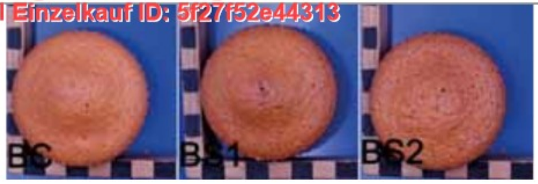
The morphological characteristic of bread and muffin crumbs including the characteristics of each cellular void and the open pore connections between them were determined by scanning of bread slices. Crumb fineness known as cell density was calculated from the total number of cells detected over total surveyed area of the crumb, as shown in Table 3. Incorporation of chia seeds in breads tend to decrease the cell density. As reported by Scheuer et al. (2015) cell density strongly influences the textural properties of bread crumb. As observed by Polaki et al. (2010) in whole oat bread, lower cell density in chia supplemented breads can be explained by the fact that fibre can dilute gluten and interfere with the starch-gluten matrix causing less gas retention. The higher cell density for the standard bread formulations can be associated with softer product which is evident in Figure 5, where the standard bread was less hard as compared to the other two formulations.

Chia seeds formulation did not affect muffin density, an indication that any macromolecular networks formed between flour components and chia seeds fibre did not



Source: Mburu, Zettel 2020

**Fig. 2:** Photograph images of the bread crumbs (Abbreviations: BC, Standard Bread, BS1, Bread supplemented with 5 % chia seeds, BS2, Bread supplemented with 10 % chia seeds)



Source: Mburu, Zettel 202

**Fig. 3:** Photograph images of muffins (Abbreviations: BC, Standard muffins, BS1, muffins supplemented with 5 % chia seeds, BS2, muffins supplemented with 10 % chia seeds)

Soucrce Mburu, Zettel 2020

**Fig. 4:** Photograph images of cookies (Abbreviations: BC, Standard Cookie, BS1, Cookie supplemented with 5 % chia seeds, BS2, Cookie supplemented with 10 % chia seeds)

**Table 3: Crumb fineness of breads and muffins**

| | BS | BC1 | BC2 |
|---|---|---|---|
| Bread Cell density | 96.14±5.77c | 91.65±5.54b | 90.89±12.55a |
| Muffin Cell density | 124.81±11.44a | 119.45±7.44a | 106.55±11.58a |

Means followed by the same lowercase letters in the same row did not differ significantly ($p < 0.05$).

Source: Mburu, Zettel /Graphic: ct 2020

restrain carbon dioxide leavening. This observation is in agreement with that observed by SHEARER and DAVIES (2005) who showed that the addition of flaxseed meal to whole wheat muffins did not affect their cell density. Appearance of baked products is influenced by the internal and external features of a product. It is one of the most crucial quality attribute of baked products correlating with product flavour and influences the visual perceptions of consumers and potential purchase of the product. In muffin preparation, the mechanism behind addition of ingredients in phases determines the quality of the baked products. The interaction of the ingredients and structure development occurs during mixing and baking. The sugar is first whipped with eggs, followed by addition of flour with baking powder, and finally milk and oil are whipped in at a higher speed to give aerated cream, the batter. Specific volume and pores distribution are closely related to the entrapped air in the batter and influences the final texture of the product. During whipping the sugar goes into solution and water in oil emulsion is formed, while the air cells are dispersed into the fat phase only. Flour addition leads in a change to a multiphase structure with air cells dispersed in a continuous phase of dispersed dry ingredients as reported by Pernell et al. (2002). During the baking stage, starch gelatinisation and protein coagulation and as well as carbon dioxide generation give rise to a semi-solid porous gel-like structure, where the rate of bubble rise is inversely proportional to the viscosity of the batter (Sahin 2019).

In bread making, the time needed for the outer region of the dough to develop some rigidity during heating for sustained expansion to take place determines the pore sizes of the crumb. Porous crumb structure in bread is dependent on the ingredients used to make the dough, processing environment especially during proofing and baking, activity of yeast activity, and gas bubble formation (Rathnayake et al. 2018).

Pore size distribution is also strong related to the processing of dough, which takes into consideration, the combination of disturbing chia seeds in the gluten network as well as the difficult step of rounding the breads. The crumb grain in bread and muffins influences the textural quality of the final product, which is dependent on the geometric and mechanical properties of the product, which heavily depends on the cellular structure of a crumb of a slice of a product (Scanlon and Zghal 2001).

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