STUDIES IN THE APPLICATION OF GREEN BANANA FLOUR COMPOSITE FROM 10 BANANA CULTIVARS IN GLUTEN-SUGAR-FREE BANANA FLOUR BASED BISCUIT

By

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Declaration

I, Tshimangadzo Malindi, certify that the dissertation entitled "STUDIES IN THE APPLICATION OF GREEN BANANA FLOUR COMPOSITE FROM 10 BANANA CULTIVARS IN GLUTEN-SUGAR-FREE BANANA FLOUR BASED BISCUIT" is my original work and a result of my investigation. I further announce that all non- original sources, resources, and findings have been propely cited and referenced. I acknowledge that this dissertation has never been applied or completed for a degree to any other organization.

Learner signature: Date:

Supervisor signature: Date:

Co-supervisor signature: Date:

Dedication

This thesis is devoted to my late father Phineas Nkhangweleni Mmbulugeni who sadly passed away 2017 August after this study journey begins. My late grandmother Maria Thidziambi Muvhango Ramathavha, Sarah Thivhonali Ramathavha and my late uncle Wilson Ramathavha.

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List of conference presentations

1. Oral presentation at 36^{th} Annual Congress of the South African Society for Agricultural Technologists (SASAT), September 18 – 21. CASA DO SOL HOTEL AND RESORT Hazyview, Mpumalanga, South Africa. Topic: Development of Gluten and Sugar-Free Biscuits based on Green Banana Composite Flour from 10 Banana Cultivars Grown in South Africa.

2. Poster presentation at the 23 Biennial International Congress & Exhibition of the South African Association for Food Science and Technology (SAAFoST), 1-4 September 2019 Birchwood hotel and conference centre, Johannesburg, South Africa. Topic: Development of gluten-sugar- free banana flour-based biscuit: Effect of ingredient concentrations on textural properties and consumer acceptability.

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Abstract

Gluten intolerance and diabetes are some of the major noninfectious sicknesses in South Africa. The influence of ingredients on the physicochemical profile of composite green banana flour-based biscuits was examined in this investigation. The main goal was to see how the ingredients affected the feel and acceptability of gluten-sugar-free biscuits. The proximate analysis of green banana composite flour, browning index, biscuit dimension, textural properties, and consumer acceptability of gluten-sugar-free banana flour-based biscuits were investigated. Biscuits were prepared from a composite flour made from 10 banana cultivars grown in South Africa. The concentrations of the main ingredients (xylitol, shortening, milk, flour) were varied between 5-55%. Biscuit dimension was measured in (mm) using a 0-200mm digital calliper. A chromaticity meter was used to determine the hue of the biscuit's surface (CR-400, Onica Minolta Co, Japan). The textural features of the resultant biscuits were tested by a TA-XT texture tester through a 2mm cylinder probe, and by consumer sensory evaluation involving 120 unexperienced panelists using a 9-point hedonic scale. Statistical analysis was done by means of one-way ANOVA with separation of means using Duncan's Multiple Range Tests. Correlations between parameters were done using a Spearman rank correlation coefficient. The data showed an increase of biscuit spread ratio with the increase of milk, shortening and xylitol percentage and biscuit spread ratio reduction noted when ingredients concentration increase to 20%. Overall browning index of biscuits baked varying ingredient concentration increased with increasing ingredient concentration. The results showed that xylitol, milk, shortening, and flour percentage affected the instrumental texture, consumer acceptability, and willingness-to-buy of the biscuits. Overall acceptability was most correlated with taste (r=0.95) and texture (r=0.95). This recommends that taste and texture were crucial drivers of liking for the consumers assessing biscuits. The willingness-to-buy was moderately correlated with taste (r=0.60) and texture (r=0.60). The present research indicated that it is possible to modulate the textural properties, consumer acceptability and willingness-to-buy, of gluten-sugar-free banana flour-based biscuits, by varying the concentration of xylitol, shortening, flour and milk added to the formulation. To identify the optimum percentage of ingredients, optimization studies are required. The resultant gluten-sugar-free banana flour-based biscuits would contribute to the alleviation of gluten intolerance and diabetes hence reduce the overall public and personal health bills associated with these non-communicable diseases.

Keywords: Gluten-free, Sugar-free, Green banana flour, Biscuit production, Xylitol, Browning index, Biscuit dimension, Biscuit Texture, Sensory evaluation

CHAPTER 1: INTRODUCTION

Bananas are generally grown in tropical and subtropical climates and are valued crop in the world's fruit industry (Bertolini et al., 2010; Menezes et al., 2011; Pacheco-Delahaye et al., 2008; Rayo et al., 2015; Rodríguez-Ambriz et al., 2008; Savlak et al., 2016; Strosse et al., 2006; Tribess et al., 2009). All around the world, banana (Musa spp.) is a significant diet produce positioned after wheat, rice and maize (Soto-Maldonando et al., 2020). They consist of dessert, plantain, and cooking banana. Plantain (Musa paradisiaca AAB) and other cooking bananas (Musa ABB) are resultant of AA and BB hybridization of Musa acuminata (AA), and Musa balbisiana (BB) (Robinson, 1996, Stover and Simmonds, 1987). Banana fruit are commonly consumed as ripe fruit worldwide and staple food in some African nations, and for restorative purposes in eastern pieces of the world (Mohapatra et al., 2011).

Since bananas have a high starch content, more than (70% dry weight), preparing them into flour and starch is a factor to consider when evaluating a potentially valuable commodity for food and other industrial uses (Aurore et al., 2009). The solid benefit obtainable from green banana flour comprises of a high total starch (73.4%); resistant starch (17.5%) and dietary fiber content (14.5%) (Juarez-Garcia et al., 2006). Because of high substance of these effective constituents, regular utilization of green banana flour can be required to present gainful medical advantages for human utilization (Rodríguez-Ambriz et al., 2008). Numeral of investigation have been directed with regard handling and use of banana flour when the banana is as yet green by incorporating the resultant flour into differents new item like cake batter (Hosseinvand and Sorkhinejad, 2018); edible cookies (Aparicio-Saguilán et al., 2007); high-fibre bread (Juarez-Garcia et al., 2006); non gluten bread (Khoozani et al., 2020; Martínez-Castaño et al., 2019); non gluten pasta (Zandonadi et al., 2012); snacks (Wang et al., 2012); bologna sausages (Alves et al., 2016); ice cream (Yangilar, 2015); instant porridge (Loypimai and Moongngarm, 2015).

Green banana flour is another method of diminishing banana squanders and the expense of producing the flour is extremely low for the food industry (Zhang et al., 2005). Banana flour produced from unripe banana through dehydration, milling and sieving (Pacheco-Delahaye et al., 2008). Banana flour does not contain gluten, is a starchy nutrition that contributes to the gluten intolerance problem (Kaur et al., 2017).

The response of items without gluten is growing that are appropriate for patients suffering from celiac disorder Salem et al. (2019), as about one per cent of global populace is experiencing gluten intolerance (Shevkani and Singh, 2014). Celiac disorder can only be treated by eliminating gluten from one's diet (Salem et al., 2019). In affluent nations, overweight is considered an widespread, with estimates that the sickness will stretch to 1.12 billion individuals by (Kastorini et al., 2011). This is frightening because obesity is linked to a variety of chronic illnesses, including diabetes, heart illness, hypertension, and several malignancies (Bray, 2004). Numerous studies have shown the significance of consuming healthy food as it helps prevent and reduce the danger of chronic disease (Li et al., 2010; Wongsagonsup et al., 2008). Biscuits are renowned food item devoured by a wide variety of customers as snacks and convenience food items in view of their diverse flavor, extended shelflife and ease preparation (Javaira et al., 2017).

Biscuits are usually made with fats, flour and sucrose making them a high-energy cereal meal (Sozer et al., 2014). Unripe banana flour mixed with other alternative flours has been used to prepare gluten-free cookies and increase the indigestible carbohydrate content Norhidayah et al. (2014), however, there have been no studies in which only unripe banana flour and xylitol was used in the production of biscuit. Production of green banana flour based biscuits from a variety of cultivars with market-required characteristics will lead to higher demand for banana farmers in South Africa and this will contribute to improved health of the population as results of consuming biscuit completed from banana flour since banana flour is gluten-free, rich in anti-oxidants and resistant starch.

1.1 Problem statement

Banana fruit is highly perishable and decay fast due to high moisture content and metabolic action (Demirel and Turhan, 2003). Unripe banana flour is considered as a economical ingredient and production of flour may help to reduce losses and increase the market share (Olorunda, 1996, Zhang et al., 2005). The strong benefits obtainable from the flour made with unripe banana include; a high total starch (about 70.0% w/w), resistant starch (17.5% w/w) and nutritional fibre content (about 14.5% w/w), (Juarez-Garcia et al., 2006). Generally, non-communicable disease (NCD) continue to be the main public health challenge responsible for large death and sickness (Habib and Saha, 2010). Diabetes is one of the four major non-communicable diseases resulted from an unhealthy diet (Allen et al., 2017). Globally, in 2012, non-communicable diseases triggered 38 million deaths, these diseases comprise of four protuberant groups': heart disease, tumors, breathing illness and diabetes annual deaths (Allen et al., 2017). Presently, South Africa is currently facing a serious health crisis, with outbreaks of transferrable sicknesses and an increase in chronic sicknesses. Chronic sicknesses are increasing in rural and urban regions, most extremely in disadvantage people living in urban areas and are causing cumulative stress on severe and chronic health-care services (Bradshaw et al., 2003; Mayosi et al., 2009, Tollman et al., 2008). If actions are not taken to combat non-communicable disease problem in South Africa, the disease is likely to rise considerably over the following years (Mayosi et al., 2009). Consumption of nutritious diet takes extra care in the current ages because of some welbeing worries of devouring a lot of fat, sugar and salt in the worldwide (Aleem et al., 2012; Hilliam, 1995).

Presently, there has been an expansion sought after for foods without gluten appropriate for people suffer from celiac sickness (Aly and Saleem, 2015; Salem et al., 2019). Shockingly, gluten-free food isn't accessible effectively in the shops and are overrated (Javaira et al., 2017). Adhering to a non gluten food is the solitary treatment for celiac sickness (CD) (Spijkerman et al., 2016). Chubbiness is a main health public problem (Agama-Acevedo et al., 2012). Consumption of sugary food can lead to fatness and other related illnesses (Nishida et al., 2004; Riedel et al., 2015). Eating of sugary product is rising in many nations and their diversity on the market is still enormous and may have a serious health challenge such as non-communicable diet-related diseases (Te Morenga et al., 2013). Banana flour utilization will also contribute to improved health of the population as a result of consuming green banana flour containing products since banana flour is gluten-free, rich in both starch and anti-oxidants (Juarez-Garcia et al., 2006). Optimization investigation are essential to decide the optimum concentrations of the ingredients and their interactions.

1.2 Motivation

The current study delved the development of gluten-sugar-free banana flour-based biscuit. The texture and sensory qualities of gluten-sugar-free banana flour-based biscuit were assessed and the results of efforts to introduce the concept to the local banana farming community and help bakers in the future to modify baking ratios for an anticipated superior banana flour-based biscuit. Development of gluten-sugar-free banana flour-based biscuit through a scientific approach is new and no research has been conducted where green banana flour composite and xylitol is utilized as one of the primary ingredients in the creation of gluten-sugar-free banana flour-based biscuits. The research was alienated into two main stages. The first phase involved the preparation and characterization of green banana flour composite prepared from 10 cultivars grown and adopted in South Africa. The second phase involved the utilization of green banana flour composite from 10 banana cultivars for development of gluten-sugar-free banana flour-based biscuit and assessing the effect of ingredient concentrations/ratios.

1.2.1 Phase 1: Preparation and characterization of green banana flour from 10 cultivars grown and adopted in South Africa.

After corn, rice and wheat, banana classified a fourth significant crop in the world (Sarawong et al., 2014). The fruits are utilized in selected foods where the simplicity of nutritiousness, small amount of lipids, minerals (potassium and calcium), and vitamins (B and C) contents are required, and thereby used in special diets for all ages and sick individuals with abdominal issues, gout and joint pain (Bezerra et al., 2013; Nakosone and Paull, 1999). When the fruit is green (bananas), it can be used as a starting point for developing new diets: Products that have been prepared and are ready to eat (Lemaire et al., 1997). According to Aurore et al. (2009), making of powder, dehydrated, complete and or as fried banana, is still underdeveloped. The flour has been utilized as an constituent of making cookies, cake batter, bread, pasta and ice cream (Fasolin et al., 2007; Hosseinvand and Sorkhinejad, 2018; Ovando-Martinez et al., 2009; Yangilar, 2015; Zandonadi et al., 2012). It is appropriate to advance processed product design to modern market anticipation by giving a more variability and accessibility for users, by production of products which can be utilized in other product preparation (Aurore et al., 2009).

1.2.2 Phase 2: Effect of ingredient concentrations on properties and consumer acceptability of gluten-sugar-free banana flour-based biscuit developed from green banana flour composite from 10 cultivars.

Celiac illness is a constant colonic malabsorption sickness characterized by completely withdraw to material like prolamins in wheat (gliadins), barley (hordein), rye (secalin), and possibly oats (avidins) (Wang et al., 2017). The lone present cure is a permanent omission of gluten and other proteins should be avoided in the diet. Various investigation indicated that the illness affects about 1% of the global populace (Wang et al., 2017). Unripe banana flour has been widely researched as a gluten-free replacement for wheat flour (Cureton and Fasano, 2009; Zandonadi et al., 2012). The flour from green banana is a economical ease constituent for the diet business (Zhang et al., 2005). Oats, wheat, rice, beans, and barley are cereal-based foods that are used as stable foods all over the world (Aleem et al., 2012a). However, flour from wheat is the most significant in terms of making and utilization among these cereals (Barak et al., 2013). Although biscuits prepared using wheat flour is still leading on the market globally Aleem et al. (2012a), currently, people are adopting the style of consuming the gluten-free product of which banana flour is among those products. Biscuits and cookies are very general items worldwide, with substantial mixtures of quality and taste giving them a universal demand (Pratima and Yadane, 2000). Making gluten-sugar-free biscuit products with green banana flour and xylitol to substitute sugar is significant to increase celiac disease (CD) and diabetic patients' food selections. This symbolizes the opportunity of growing and expanding of banana farmers and biscuit bakers market.

1.3 Study hypothesis

In some studies, banana flour was incorporated with wheat flour and different crops for the production of biscuit and cookies (Norhidayah et al., 2014). Then again, there have no studies comparing sensory and textural properties of a gluten-sugar-free banana flour-based biscuit without incorporation with other crops flour and where xylitol is used to substitute sucrose. It is thus hypothesized that substituting xylitol for sucrose as a sweetener and using gluten-free flour would substantially help those with diabetes and celiac disease, allowing them to enjoy gluten-sugar-free biscuits. Biscuit texture and sensory properties resulting from green banana flour composite based biscuit will significantly affect the sensory properties. Xylitol has been drawing worldwide attention due to its sweetener influence comparable to sucrose and it provides 0.2-3.0. Kcal/g vitality of which is fewer from the sucrose 4.0 Kcal/g (Islam, 2011). This effectively provides a suitable sugar substitute for the production of low-energy foods (Mushtag et al., 2010; Russo, 1977).

1.4 The research objectives

1.4.1 Main objective

To determine how ingredient applications affect the physical and sensory qualities of gluten-sugar-free banana flour biscuits developed from composite flour of 10 banana cultivars grown in South Africa. This considers the fact that gluten intolerance and diabetes are some of the major non-communicable diseases in South Africa. With a quick-moving world, different food habits, demanding lifestyle, overall quality of life is essential for a well gastrointestinal system is more acquainted (Brouns et al., 2002).

1.4.2 Specific objectives

1. To evaluate variations in banana flour based gluten and sugar-free biscuit physical characteristics (texture, browning index and biscuit dimension) baked with different concentration of the main ingredients (xylitol, flour, shortening, milk) varied between 5-50% w/w.

1.5 Layout of the study

Chapter 1: The chapter display the research project and an overview of the study. The reason for introducing this study is indicated on problem statement giving the details for introducing this investigation. Motivation, aim and hypothesis are also present expressing the problem relating to the study. Chapter 2: This chapter presents an overview outlook of existing information of physico-chemical properties of green banana flour preparation, details the production of gluten-sugar-free banana flour-based biscuit. This chapter also clearly an emphasis on gluten-free baked product, obesity, diabetes and xylitol. Chapter 3: This chapter emphasis on sample selection and research, preparation and mixing of green banana flour composite from 10 banana cultivars and particle size. Chemical analysis of composite banana flour for moisture, protein, crude fibre and ash. Biscuit physical analysis (measuring of biscuit spread ratio, browning index, dough and biscuit texture and consumer acceptance of gluten-sugar-free banana flour based biscuit). Chapter 4 and 5: This chapter emphasis on gluten-sugar-free biscuit development. Present the study's detailed findings, discussion, conclusion and reccomendations of the study.

CHAPTER 2: LITERATURE REVIEW

2.1 Banana fruit

Banana is a perennial herb, developed abundantly in tropical and subtropical areas in the world (Rayo et al., 2015). The word banana comprises dessert, plantain and cooking bananas, which are the hybrids of two different wild banana species, namely *Musa acuminate* (AA) and *Musa balbisiana* (BB) genomes. Dessert bananas (AAA) are derived from the pure acuminate group. They are sweeter and less starchy than the *Musa sapientum* or *Musa paradisica* or plantain (Robinson, 1996; Stover and Simmonds, 1987). Unripe banana fruit contains little sugar and a lot of starch, as well as a lot of bitter compounds (part of latex). Starch is converted into sugar when banana fruit ripens and the ripened banana finally has about 25% sugar with the latex broken down (Arvanitoyannis and Mavromatis, 2009).

The fruit is normally consumed ripe not green around the world, consequently, unripe banana is processed into different products, either fried banana chips, dehydrated banana chips, cooked or steamed, banana flour and banana starch (Mohapatra et al., 2011). Around the world, tropical and subtropical region societies consume banana fruit as part of their daily intake (Rodríguez-Ambriz et al., 2008). Bananas at the green phase are characterized as an substitute source of indigestible carbohydrates, such as particularly a great resistant starch content (Juarez-Garcia et al., 2006). Because unripe bananas contain 70% of dry weight levels of starch, processing of unripe banana for powder has earned interest as a possible source of food and industrial determinations (Pelissari et al., 2012). Powder from unripe banana could be a basis of natural antioxidant (Vergara-Valencia et al., 2007). The powder has been investigated as a functional ingredient, and it is expected that daily use can provide health benefits (Menezes et al., 2011; Rayo et al., 2015).

2.2 Processing step of green banana flour

Banana processing into flour is gaining more attention since excess fruits often accessible year-round in the production areas (Dame and Sahu, 2016). In the processing of banana flour, green bananas are washed, peeled, dried, milled and sieved to get the flour (Jirukkakul and Rakshit, 2011). The processed green banana flour is non-perishable and contains moisture content below 13% (Venkataseshamamba et al., 2017). The flour from unripe banana has a long shelf life and storability potential, but the flour's composition varies depending on the banana's drying process (Haslinda et al., 2009). The flour mostly used as food ingredients or as drugs with valuable properties (Rodríguez-Ambriz et al., 2008). Globally, different methods have been experimented in the processing of flour from unripe banana and several studies have been reported on banana cultivars, treatment, drying and milling method and technology. The principles of preservatives, drying and milling summarized below.

- **Preservatives**: Browning is the main concern linked by the means of extension of lifespan of fresh-cut fruit and intensely affects the buyers buying decision. Usually, for anti-browning sulphites have been used. Dispite the fact that sulphites have numerous allowed utilizes, their principal purpose is preventative or antioxidant to decrease decay (Claudia and Francisco, 2009; Taylor et al., 1986). Sulphites are also used to advance the look and taste of a variety of foods during preparing, storing, and dissemination by settling the product color and inhibiting decolorization (Claudia and Francisco, 2009).

- **Drying**: Drying is certainly the most traditional methodologies for the preservation of agricultural product completed by decreasing their moisture content (Curvello et al., 2010). The dehydrating process is employed to preserve the nutritional quality of agricultural product and explained as the extraction of volatile constituents of a solid product or where the water activity of a product reduced by dehydration (Curvello et al., 2010). Moreover, dried products offer many benefits including storage stability, lowering packaging and reducing transportation cost (Doymaz, 2010). Due to the significance of drying process to enterprises, fruits and vegetables have been dried using a variety of methods, including solar, sun, microwave, and freeze-drying (Santos and Silva, 2008). However, for a high nutritive and sensory characteristic dried product, traditional dehydrating approaches with adjusted atmosphere have also been used (Santos and Silva, 2008).

- **Milling**: The practice of flour milling has evolved alongside baking, moving from the home to the community to large-scale operations (Campbell et al., 2012). Flour production consists primarily of grinding or milling and sifting (Campbell et al., 2012). Flour processing is made up of processes that transform simple raw material into a valuable commodity for a variety of other processors, such as bakers, as well as for home consumers (Campbell et al., 2012).

2.3 Fried banana snacks, banana starch and boiled banana.

Generally, green banana snacks completed by browning the stripped banana cuts in cooking oil (Mohapatra et al., 2011). Frying of banana snacks is an easy, fast and low-cost method of cooking and manufacturing food with acceptable sensory characteristics which is a starchy product produced in a continuous method (Adeva et al., 1986; Mariano et al., 1969; Rojas-Gonzalem et al., 2006). In the world diet, starch is the key significant carbohydrate contained in bran, rhizomes and green crops (Agama-Acevedo et al., 2012). It account for 90% of entirely cellulose in diet and it can be classed as digestible or resistant and it's becoming more popular as a results of its health reliefs (Fasolin et al., 2007; Langkilde et al., 2002). For starch making, sliced green banana pulp macerated in a blender, sieved through a mesh screen, resulted in starch milk, allow to settle for 3 hours, the resultant sediments are washed again until revealed a uniform white colour, the produced starch is dried and milled (Pelissari et al., 2012).

Primarily, thickener or starch is in control of technical things that show various preserved diet items, as it provides a variety of food quality properties and has a wide range of uses as a starch, mixture stabilizer, paste and sauces (Vandeputte et al., 2003). The starch content of bananas in their green phase is high, basically as resistant type 2 (Cano et al., 1997; Gutierrez et al., 2008). Unripe banana also measured richest natural source of resistant starch, though, this feature is no longer present when the fruit is cooked (Rodríguez-Damian et al., 2012). Boiled green banana completed by boiling banana in hot water, generally, green banana of nearly entire dessert and cooking bananas boiled in hot water subject on the banana cultivar and eaten with numerous sauces (Newilah et al., 2005).

Figure 1 shows a flow diagram of green banana flour processing, figure 2 shows commonly processed green banana product and various preservative methods and the technology used for drying and milling of unripe banana flour are shown in Table 1.

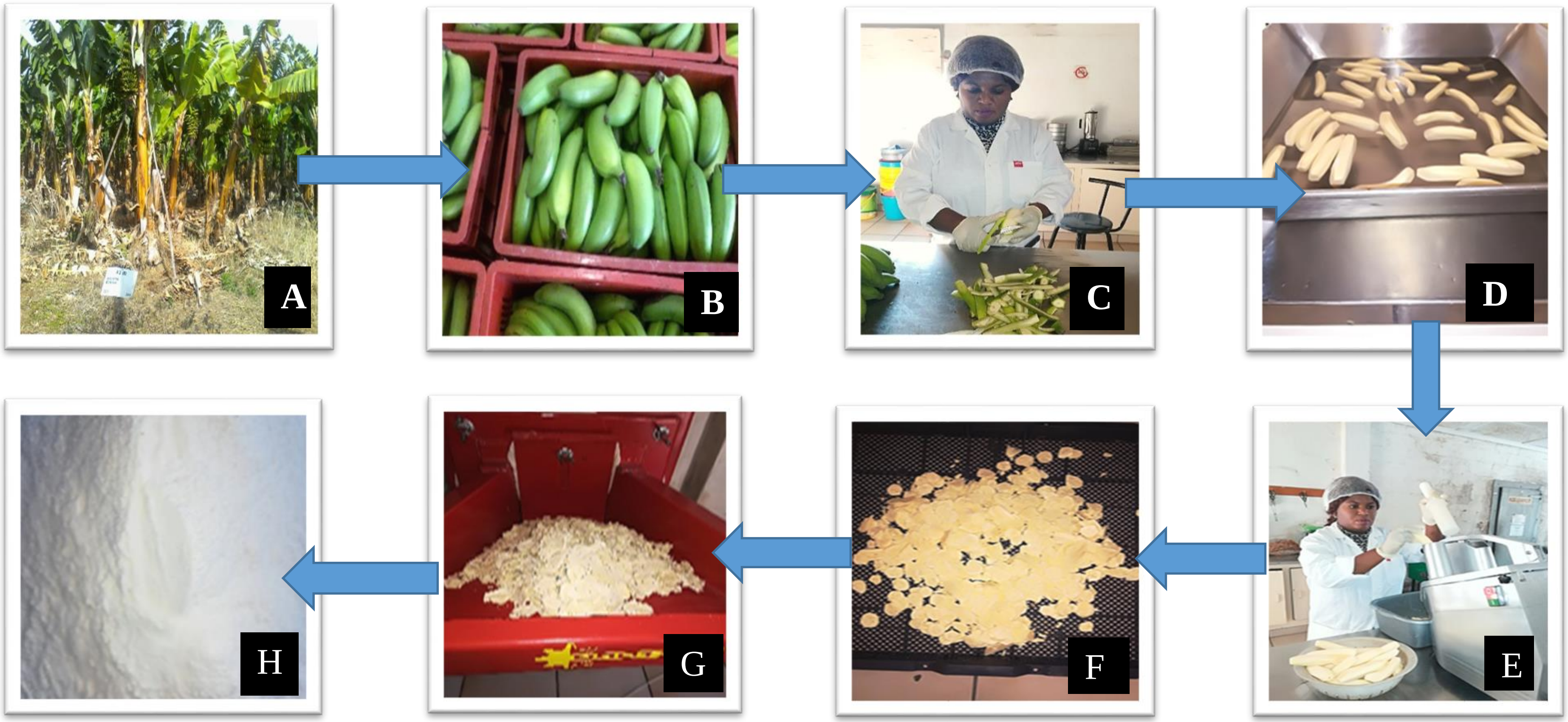


Figure 1: Flow diagram of green banana flour production. (**A**) banana plantation, (**B**) green banana, (**C**) peeling, (**D**) preservation of banana pulp, (**E**) cutting, (**F**) banana pulp, (**G**) milling and (**H**) green banana flour.

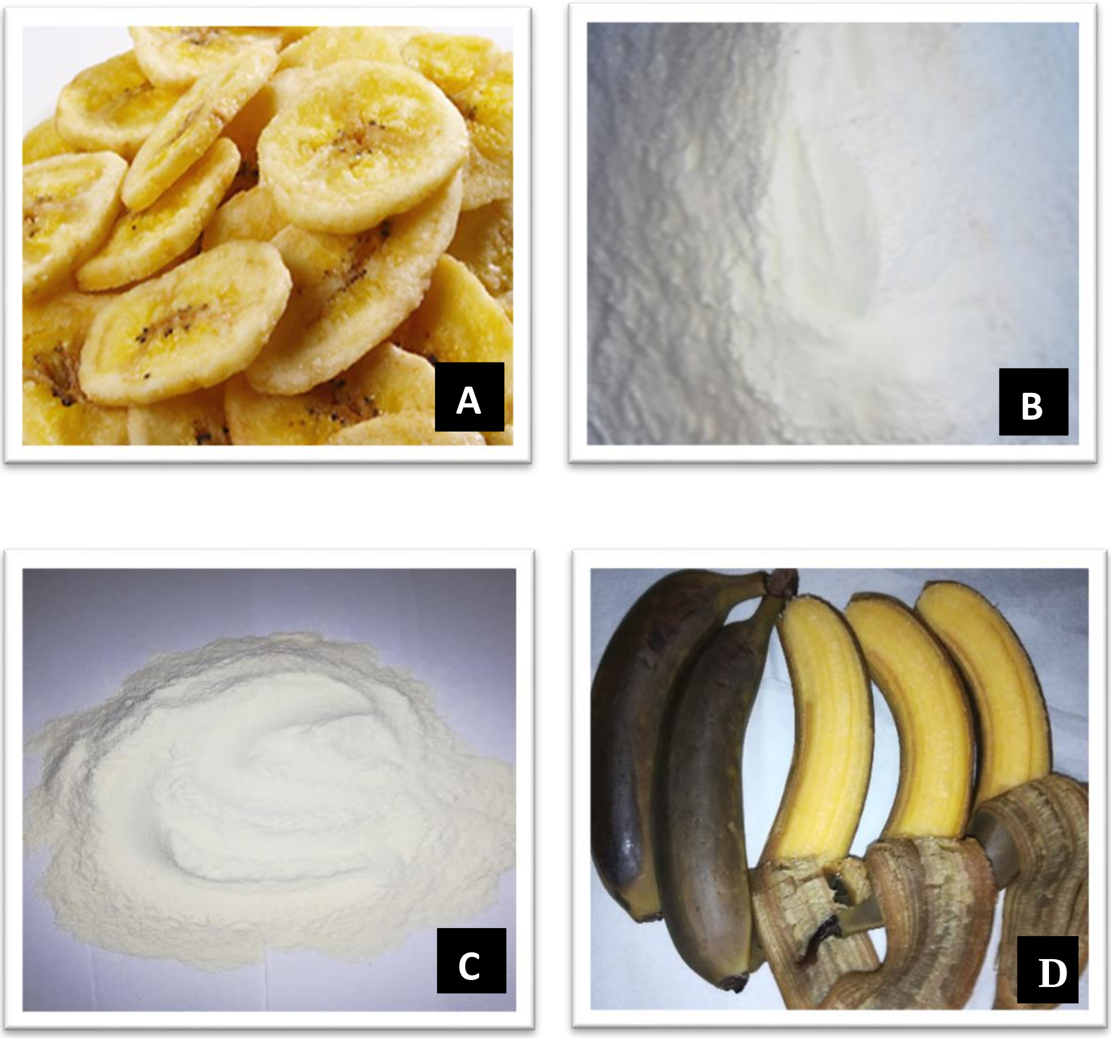


Figure 2: Commonly processed unripe banana product. (**A**) unripe banana snacks, (**B**) unripe banana flour, (**C**) unripe banana starch and (**D**) boiled unripe banana.

Table 1: Various preservatives methods, technologies used for drying and milling of green banana flour production

Banana pulp	**Preservatives**	**Technologies used for dehydration**	**Technologies used for milling**	**References**
Green banana pulp	Citric acid solution (10g L^{-1})	Dehydrated at 55^0C of air velocity in a pilot plant-scale forced dryer (Proctor & Schwartz, EQ-EP.134,USA)	Crushed in a mill (Rietz, RP-8-K115,USA)	(Rayo et al., 2015)
Green banana pulp and peel	Sodium hypochlorite solution (20 ppm) for 10 minutes	Dried in a commercial dehydrator at 60^oC	Ground in a blender for 5 minutes	(Yangilar, 2015)
Banana pulp	Citric acid solution (0,3% w/v).	Dried at 50^0C in a convection oven	Milled using a commercial mill (Masipa International S.A. de C.V., Mexico, D.F.) to pass a US 50 sieve	(Ovando-Martinez et al., 2009)
Plantain slices	1% citric acid	Tray-drying accessory and kept at -18^0C for 24h. and lyophilized for 5h in a freezone yophilizer (Labconco;Missouri, USA)	Milled in a Hammer mill to pass sieve size of 0.01mm.	(Pacheco-Delahaye et al., 2008)

Table 1. (Continued): Various preservatives methods, technologies used for drying and milling on green banana flour production

Banana pulp	Preservatives	Technologies used for dehydration	Technologies used for milling	References
Green and ripe banana peel and pulp	Citric acid	Dehydrated in oven (AFOS Mini Kiln at 60^0c overnight)	Milled in Retsch Mill Laborotory (Retsch AS200) completed with 60 and 40 sieve net screen	(Alkarkhi et al., 2011)
Green banana pulp	Citric acid	Dried in a freeze dryer (CRYST-Alpha 2-4 LD Plus Freeze Dryer, Newtown Wem, Shropshire, UK)	Crushed using blade grinder (Retsch, GRINDOMIX GM200, Germany) and completed with sieve shaker (Simsek Laborteknik, ES-608, Turkey) of different fraction sizes	(Savlak et al., 2016)
Green banana pulp and peel	Immersed in 0.3% citric acid solution	Oven-dried at 42^0C for 72h	Ground separately in a hammer mill (Perten mod. 3170) pass through 0.5 mm mesh sieve	(Bertolini et al., 2010)
Green banana pulp	Blanching in hot water at 60°C, 80°C and 100°C for 5,10 and 15 minutes	Dried in the air oven at 65^0C (24/h)	Milled in a hammer mill to pass through a 500 µm mesh	(Oluwalana et al., 2011)

Table 1. (Continued): Various preservatives methods, technologies used for drying and milling on green banana flour production

Banana pulp	Preservatives	Technologies used for dehydration	Technologies used for milling	References
Green banana pulp	Citric acid solution 0.3% w/v	Dried at 50^0C in a convection oven	Commercial crusher (Masipa International S.A. de C.V., Mexico, D.F) completed using US 50 sieve size	(Juarez-Garcia et al., 2006; Rodríguez-Ambriz et al., 2008)
Green banana pulp	Citric acid solution (1g/l)	Dehydrated at 55^0C and an air velocity of 1.0 m/s pilot plant-scale tray dryer (Proctor and Schwartz, model K11556, Philadelphia, USA)	Milled using MA 680 mill (Marconi, Piracicaba, Brazil) to 250 µm.	(Menezes et al., 2011)
Green and ripe plantain pulp	0.02% sodium metabisulphite and blanched at 100^0C	Oven dried at 67^0C using a Gallenkamp air oven	Milled using a hammer mill (Armfield) and sieved to pass through a 500 µm sieve	(Fagbemi, 1999)
Green banana pulp	Citric acid solution	Dehydrated in a small scale plate oven UOP8 (Armfield, England for about 6 h (from 5.6h to 6.8h), changing the air heats	Ground to 250 µm	(Tribess et al., 2009)

Table 1. (Continued): Various preservatives methods, technology used for drying and milling on green banana flour production

Banana pulp	**Preservatives**	**Technologies used for dehydration**	**Technologies used for milling**	**References**
Green banana pulp	Citric acid solution 0.3% w/v	Dried at 50^{0}C in a convection oven	Commercial grinder (Masipa International S.A. de C.V., Mexico, D.F) completed using US 50 sieve size	(Hosseinvand and Sorkhinejad, 2018)
Green banana pulp	Sodium metabisulphite	Commercial scale hot-air forced convection dryer (AD3000 Agri-Dryer, Dryers for Africa, SA)	Laboratory scale rotor beater mill (SR 300, Retsch, Germany) with a 500 m mesh	(Kongolo et al., 2017)
Green banana pulp	Potassium metabisulfite solution (1%)	Air convection oven at 45^{0}C for 48 h	Powdered in a knife mill (Marconi model MA340, Sao Paulo, Brazil) successively sifted using screens (115, 150, 170, and 200 US mesh)	(Pelissari et al., 2012)
Luvhele (Musa ABB) Mabonde (Musa AAA) and Muomva-red (Musa balbisiana) Pulp	Organic acid: Citric, lactic and ascorbic citric	Vacuum dried in an oven	Unripe banana flour was milled using (Retsch ZM 200 crusher, Haan, Germany) at 16,000rpm for 30 s	(Anyasi et al., 2015)

2.4 Proximate analysis of green banana flour and plantain

When determining the superiority of unprocessed material, the proximate composition is important as it is frequently the starting point for determining nutritional value and complete consumer recognition (Moses et al., 2012). Examination of proximate composition offers evidence for basic chemical composition in food such as ash, crude fibre, crude protein and moisture content, these constituents are important for valuation of the nutritive quality of the food being investigated (Zakpaa et al., 2010). Thorough sampling is essential to attain correct reliable values or outcomes (Zakpaa et al., 2010). Analyses typically completed on slight separate samples rather than the whole quantity of foodstuff (also called a perfect sample). Several procedures (grinding, mixing, sieving, weighing etc) are utilized to make sure that slight tasters are illustrative of the whole substance and give a precise ration of its complete content (Zakpaa et al., 2010). Numerous investigation have been carried out on the proximate analysis of unripe banana flour. Table 2 shows crude protein, crude fibre ash and moisture content of green banana and plantain flour from different studies.

Table 2: Proximate investigation of green banana and plantain flour

Banana/plantain flour/ripe and unripe	Banana cultivar	**Moisture (g/100g)**	**Ash (g/100g)**	**Crude fibre (g/100g)**	**Protein (N_{total}) (g/100g)**	**References**
Unripe banana flour	Red skin	11.5	1.00	0.20	1.95	(Daramola and Osanyinlusi, 2006)
Unripe banana flour	(*Musa acuminate* Colla var. Nanicão)	7.77	3.16	-	0.61	(Bertolini et al., 2010)
Unripe plantain flour	Tera (*Musa paradisiaca*)	8.00±0.02	1.92±0.10	1.18±0.07	3.16±0.10	(Pelissari et al., 2012)
Unripe banana flour	(*Musa paradisiaca* L)	7.1±0.05	4.7±0.13	-	3.3±0.4	(Juarez-Garcia et al., 2006)
Unripe banana flour	-	6.0±0.1	4.4±0.1	-	3.4±0.3	(Rodríguez-Ambriz et al., 2008)
Unripe plantain flour	-	3.14±0.22	2.68±0.050	0.979±0.167	2.682±0.050	(Zakpaa et al., 2010)
Unripe plantain flour	-	5.10±0.06	2.00±0.04	1.33±0.20	3.51±0.10	(Fagbemi, 1999)
Unripe banana flour	Poyo	11.7	3.60	0.40	3.25	(Daramola and Osanyinlusi, 2006)
Unripe banana flour	-	6.63±0.06	0.59±0.06	1.46±0.02	2.19±0.03	(Thakur et al., 2016)
Unripe banana flour	Cavendish (*Musa acuminate L, cv Cavendish*)	7.21±0.01	3.79±0.001	2.56±0.004	3.75±0.02	(Ramli et al., 2009)

Table 2 (continued): Proximate investigation of green banana and plantain flour

Banana/plantain flour/ripe and unripe	Banana cultivar	**Moisture (g/100g)**	**Ash (g/100g)**	**Crude fibre (g/100g)**	**Protein (N_{total}) (g/100g)**	**References**
Unripe banana flour	-	7.75±0.12	2.67±0.01	-	4.43±0.90	(Ovando-Martinez et al., 2009)
Unripe banana flour	Prata (*Musa sapientum*)	3.53±0.07	2.25±0.05	-	4.57±0.35	(Batista et al., 2017)
Unripe banana flour	(*Musa sapientum* L. Linn., group, Kluai Namwa)	4.77±0.37	2.58±0.49	-	2.77±0.45	(Dangsungnoen et al., 2012)
Unripe banana flour	Musa spp Poovan (AAB)	7.7	2.40	2.0	1.05	(Selvamani et al., 2009)
Unripe banana flour	Musa spp Monthan (ABB)	8.4	2.54	1.7	1.45	(Selvamani et al., 2009)
Unripe banana flour	Musa spp Karpuravalli (ABB)	8.3	1.20	1.8	3.25	(Selvamani et al., 2009)
Unripe banana flour	Musa spp Pachai (AAA)	7.9	2.80	1.0	1.73	(Selvamani et al., 2009)
Unripe cooking banana flour	*Cardaba*	10.34±0.01	4.62±0.01	0.85±0.02	4.49±0.16	(Onwuka et al., 2015)
Unripe cooking banana flour	*Bluggoe*	10.00±0.24	3.83±0.15	0.71±0.05	4.79±0.03	Onwuka et al., 2015)
Unripe banana flour	Gross michel	11.1	0.55	0.45	1.05	(Daramola and Osanyinlusi, 2006)

Table 2 (continued): Proximate investigation of green banana and plantain flour

Banana/plantain flour/ripe and unripe	Banana cultivar	**Moisture (g/100g)**	**Ash (g/100g)**	**Crude fibre (g/100g)**	**Protein (N_{total}) (g/100g)**	**References**
Unripe plantain flour	-	5.00±0.04	2.40±0.25	1.30±0.12	3.52±0.10	(Osundahunsi, 2009)
Ripe plantain flour	-	6.80±0.24	2.20±0.10	1.89±0.22	3.50±0.09	(Osundahunsi, 2009)
Unripe banana flour	Cavendish	12.1	0.85	0.70	1.75	(Daramola and Osanyinlusi, 2006)
Unripe banana flour	Lacatan	10.9	0.92	0.30	2.00	(Daramola and Osanyinlusi, 2006)
Unripe banana flour	Dwarf Cavendish	10.8	0.85	0.65	1.45	(Daramola and Osanyinlusi, 2006)

2.5 Particle size distribution

Generally, granule mass is an significant quality factor of flour as it influences the handling procedures as well as finished product superiority, particularly on account of wheat flour (Patwa et al., 2014; Sullivan et al., 1960). The particle size distribution of substances is crucial in determining physicochemical properties during the processing of products such as the manufacturing of food powder, substances, colourants, decorates and medicines whereas the sieves or screen are probably oldest and most widely used working elements of particle or granular separation (Liu, 2009). Jillavenkatesa et al. (2001) reported that particle size distribution of powder or granular material attributes a scientific function which describes the relative amount, classically by weight of particles present according to size. According to Hareland, (1994); Patwa et al. (2014); Sonaye and Baxi, (2012), different methods utilized for powder particle size analysis comprising screen or sieve analysis, sedimentation, microscopy, and laser diffraction.

2.5.1 Sieving investigation

Sieve investigation is a technique utilized in manufacturing to regulate the molecule dimensions dissemination of granular in a broad variety of industrial powder processing, including food powders, additives, colorants, paints, and pharmaceuticals (Dong et al., 2009; Liu, 2009; Sonaye and Baxi, 2012). According to Wu et al. (1990), when a series of sifters is used, the mean particle size is more accurate than when a single screen is used. In cereal science, the subject of flour particle size has fascinated many investigators, mostly for its effect on flour quality (Neale, 1997). According to Sonaye and Baxi, (2012), a weighed flour taster is decanted into the sifter with the biggest sifter opening, the top mesh. The openings of the lower sieves in the column are narrower than those of the upper sieves. Normally, the column is shaken by a mechanical shaker. After the flour on each sieve has been shook, it is weighed. The complete load isolates the heaviness of the flour from each sifter, resulting in a rate kept on each strainer.

The following equation is commonly used to determine the percentage of collective transient by mesh and the retained percentage in each mesh:

$$\frac{Wsieve}{Wtotal} \text{ x } 100\% \qquad 1$$

W_{Sieve} = weight of aggregate in the sieve

W_{total} = total weight of the aggregate

Equation adapted from: (Sonaye and Baxi, 2012)

2.6 Biscuit production

Biscuits are made from flour, sucrose, shortening, and milk and are one of the most widely consumed nutritional snack items on the planet (Adebowale et al., 2012; Ghallas et al., 2008; Hui, 1992). Sucrose and shortening are one main important materials of bakery products, providing size, texture, sweetness, flavour, mouthfeel and it contributes to form, deliciousness, quality and lubricity of biscuit (Zoulias et al., 2002). The main constituents used in the preparation also regularly being used to categorize the cookies are, chocolate, caramel, ginger, or nut cookies (Norhidayah et al., 2014). The snacks are suitable for all age groups and advance into the best dessert (Hooda and Jood, 2005; Rababah et al., 2006). Biscuit regarded as a desiccated product with low moisture content and are known as cereal product. Biscuit is categorised as a hard and soft dough (Idoko and Nwajiaku, 2013). Hard dough biscuit preparation consists of little fats or shortening and little sucrose content and more water or milk content, whereas soft dough biscuit preparation consists of more sucrose and shortening with less water or milk content (Idoko and Nwajiaku, 2013).

Consumer demand for health-conscious foods has sparked the creation of a new bakery items enhanced by bioactive ingredients (Fradinho et al., 2015). Researches have been conducted on the production of cookies and biscuit without using wheat flour as the main ingredients (Norhidayah et al., 2014). Due to their ready-to-eat form, extensive use, decent eating consistency, and long shelf life, biscuits have the potential to be a better composite flour activity than bread (Okpala and Chinyelu, 2011; Sharma and Chopra, 2015).

2.6.1 Biscuit ingredients

2.6.1.1 Flour

Flour is the product of an agricultural commodity that is variable in quality and hence flour itself is subject to erraticism (Campbell et al., 2012). Color, particle size distribution, ash, water absorption, and even microbial counts are all factors that are closely monitored when it comes to flour quality (Campbell et al., 2012). The flour sort is key in attaining superior baked goods.

Bread flour, for example, complete by strong wheat with a high protein content and a high level of starch destruction (Edwards, 2007). Conversely, flour with small amount of protein content and that is resistant to starch damage are utilized for biscuit creation (Edwards, 2007). In addition, the handling of bakery flour differs. Flour for making biscuit functions as a reducing agent, while flour for making bread functions as a rusting agent (Edwards, 2007).

Mixture or blend of flour, starches and other variety of ingredients is prepared likely to substitute wheat flour completely or somewhat in confectionary and pastry product (Milligan et al., 1981). Composite flours are made up of two or more flours from various yields, including or excluding wheat flour (Shittu et al., 2007). Composite flour lessens the importation of wheat flour measured beneficial in emerging states and it lessens wheat flour import, and boosts the utilization of nearby developed harvests as flour (Hasmadi et al., 2014; Hugo et al., 2000). The bakery product made from blend of flour is of acceptable quality with certain characteristics that are similar to those found in wheat flour. The quality and features of products from mixture of flour, on the other hand, vary with the flour produced with wheat flour, with superior nutritious value and texture (Dhingra and Jood, 2001; Noorfarahzilar et al., 2014).

2.6.1.2 Sugar

Sucrose is the most significant sugar in cookie production (Pareyt et al., 2009). Sucrose is an important ingredient in various diets together with bakery items like cakes and biscuits. Sugar adds sweetness, texture, flavor and color to these products (Majzoobi et al., 2016; Manohar and Rao, 1997). Sugar variety, quantity, and granule size, among other factors, influence product quality by boosting the volume of dissolved sucrose, gluten linkage development, and starch gelatinization (Perey et al., 2008; Smith, 1972).

2.6.1.3 Fats

Fats are an significant constituent in biscuit and baked product development because they provide richness, and softness to enhance flavor, mouthfeel and texture (Manohar and Rao, 1999; Rodríguez-García et al., 2013; Zoulias et al., 2002). The type and quality of fat employed has an effect on the shortening result, and thus the biscuit quality. Once the dough has more lipid content, the lubricating effect is more pronounced, and only little quantity of fluid is needed to complete the anticipated stability, resulting in less gluten formation during mixing (Manohar and Rao, 1999). Fats contribute to cookie spread and appearance and make biscuit more easily frangible (Maache-Rezzoug et al., 1998).

2.6.1.4 Water

Water is an essential constituent of dough and baked products (Ruan et al., 1999). Water added to flour in the course of mixing, which is fundamentally a hydration process (Ruan et al., 1999). For gluten development water is essential and is involved in range of interactions and chemical reactions that take place during mixing and baking (Ruan et al., 1999). In order for flour dough to stretch, sheeting and molding, water is vital (Webb et al., 1970).

2.7 Colour measurement

Colour is the major quality feature of food assessed by customers and a significant constituent of food quality relevant to market approval (Wu and Sun, 2013). The surface of food is the most essential variables in evaluating its quality. The best vital factors influence the superiority of food produced is its surface (Francis, 1995). The first experience that a consumer notices and uses to either accept or reject food is the appearance of the food, which is usually determined by surface color (León et al., 2006). Colour dimension can be directed in two ways: visual or human assessment and instrument analysis like colourimeter or computer vision. The color of foods is assessed visually based on their characteristics using the senses. Visual colour measurement involves competent assessors in well-illuminated place without an instrument and seldom with the guide of pigment values which to match the taster colour detected (Melendez-Martinez et al., 2005).

On account of instrumental methods, colour is communicated through the pigmentation coordinates. Pigmentation can be measured using colorimeters or spectrophotometers, which have been widely utilized in the food sector for color dimension (Balaban and Odabasi, 2006). Pigment may be measured instrumentally employing both colourimeters or spectrophotometers, for color measuring, these equipment have been widely utilized in the food business (Balaban and Odabasi, 2006). Browning is the term used in the bakery industry to describe how a product's color changes after baking (Purlis, 2010). The browning index (BI) is critical for describing overall variations in brown color (Quitão-Teixeira et al., 2007). There are numerous colour coordinate systems to describe the colour of an object (Clydesdale and Ahmed, 1978). Parameter +a* values of a reddish colour and -a* values of the greenish colour, +b* of yellowish colour and -b* values for the bluish ones whereas $L*$ is a suitable dimension of brightness therefore respectively colour can be considered as equivalent to a member of the greyscale, between 0 = black and 100 = white (Granato and Masson, 2010). The most significant equation in flour colour grading are Flour colour index (FCL), Chroma (C*), Hue angle (h*), Whiteness index (WI), Yellowness index (YI) and are determined as follows:

Flour colour index (FCL) =L*- b* 2

Chroma (C*) = $(a^{*2} + b^{*2})^{1/2}$ 3

Hue angle (h*) = $\tan^{-1}\left(\frac{b*}{a*}\right)$ 4

Whiteness Index (WI) = $\sqrt{(100 - L*\ 2)) + a*^2 + b*^2}$ 5

Yellowness Index (YI) = $\frac{142.86b*}{L*}$ 6

Equations adapted from: (Pathare et al., 2013)

2.8 Texture analysis

Both of the product's rheological and structural features as experienced by automatic, tangible, and, wherever suitable, graphic and aural receptors are referred to as food texture (Lawless and Heymann, 1998). Texture characteristics also play a vital role in screening and superiority control used in the food chain and at the conclusion around handling procedure on product shelf-life and end-user liking and approval (Chen and Opara, 2013). Texture analysis is amomg the most significant consistency aspect applied in the processing of garden-fresh and treated diets to determine produce supremacy and satisfaction (Chen and Opara, 2013). Hardness, adhesiveness, and cohesiveness are commonly used in textural profile analysis to evaluate sensory consistency and rheological properties of certain foods (Friedman et al., 1963; Nishinari et al., 2013). Food textural content may be assessed using explanatory or contributory analysis (Chen and Opara, 2013). Sensory assessment encompasses completely methods for measuring, analyzing, and interpreting human reactions towards the food properties and resources as experienced by the five senses: palate, aroma, trace, view and earshot (Civille and Oftedal, 2012; de Liz Pocztaruk et al., 2011).

For the past years, distinct contributory trials have been applied in research and commerce space to measure food texture, however, the choice of each instrument and analytical technique subjected on the costs and availability of expertise within the industry (Chen and Opara, 2013). The most popular methods for determining food texture are compression and puncture tests. Texture profile analysis (TPA) is a technique that uses double-compression cycles to simulate the mastication or chewing process (Chen and Opara, 2013). Feel effects such as stiffness, springiness, cohesiveness, adhesiveness, resiliency, factorability, wateriness, gumminess, sliminess, and chewiness, as well as other parameters, can be studied using texture profile analysis (TPA) (Guiné and Barroca, 2012; Jaworska and Bernas, 2010). Table 3 shows the classification of textural characteristics and table 4 shows definitions of mechanical parameters of texture.

Table 3: Classification of textural characteristics (connections between textural parameters and popular nomenclature)

Textural characteristics		
Main parameters	***Minor parameters***	***Popular terms***
Hardness		Soft – Firm - Hard
Cohesiveness	Brittleness	Crumbly – Crunchy - Brittle
	Chewiness	Tender – Chewy - Tough
	Gumminess	Short – Mealy – Pasty Gummy
Viscosity		Thin - Viscous
Springiness		Plastic - Elastic
Adhesiveness		Sticky – Tacky Gooey
Geometrical characteristics		
Class		**Examples**
Particle size and shape		Gritty, Grainy, Course, etc.
Particle shape and orientation		Fibrous, Cellular, Crystalline, etc.
Other characteristics		
Main parameters	**Minor parameters**	**Popular terms**
Moisture content		Dry – Moist – Wet - Watery
Fat content	Oiliness	Oily
	Greasiness	Greasy

Table 3 adapted from: (Szczesniak, 1963, 2002)

Table 4: Classifications of mechanical parameters of texture

	Somatic	**Sensual**
Main properties		
Hardness	The amount of force required to achieve a specific deformation	Force needed to crush a substance between molar teeth (in the case of solids) or tongue and palate (in the case of liquids) (in the case of semi-solids)
Cohesiveness	The maximum deformation that a material can take before it ruptures.	The amount of pressure applied between the teeth before a substance breaks.
Viscosity	Flow rate per unit force	Power needed to pull a liquid from a spoon over the tongue
Springiness	After a deforming force is removed, the rate at which a distorted material returns to its original state.	The amount of time it takes for a product to return to its original shape after being squeezed between the teeth.
Adhesiveness	Work required to overcome the attraction forces that exist between the food's surface and the surfaces of other materials with which it comes into touch.	Strength needed to eliminate the material that adheres to the mouth (generally the palate) during the normal eating process

Table 4 adapted from: (Szczesniak, 2002)

Table 4: (Continued): Classifications of mechanical parameters of texture

	Somatic	**Sensual**
Minor properties		
Fracturability	A material having a high degree of hardness and a low degree of cohesiveness fractures with a high force.	Power with which a sample crumbles, cracks, or shatters
Chewiness	The amount of energy necessary to masticate a solid food into a swallowable state: a combination of toughness, cohesion, and springiness	Time required to masticate the sample at a constant rate of force application in order to reduce it to a consistency acceptable for swallowing (in seconds).
Gumminess	The amount of energy necessary to dissolve a semi-solid food into a swallowable state: a product with a high degree of cohesion and a low degree of hardness	Density that lasts throughout mastication; the amount of energy necessary to dissolve a semi-solid food into a swallowable form.

Table 4 adapted from: (Szczesniak, 2002)

2.9 Celiac disease

Celiac disease (CD) is an immune-mediated enteropathy marked by lifelong concerned to gluten and thereby intolerance to wheat-containing foods (Fasano et al., 2008). Celiac disease (CD) is a small intestine disease for which the only current cure is to exclude gluten from the diet, which translates to not consuming wheat-containing foods (Eckert et al., 2006). Some studies indicated that celiac sickness affects almost one percent of global society (Catassi and Fasano, 2008; Mustalahti et al., 2010). As the number of people requiring such a diet has grown, so has the need for gluten-free foods (Nijeboer et al., 2013; Witczak et al., 2016). Celiac disease (CD) is characterized by malabsorption symptoms such as steatorrhea, abdominal pain, weight loss or gain, fatigue, anemia, and extreme diarrhoea, and it can affect people of all ages (Fasano and Catassi, 2001; Feighery, 1999; Moore et al., 2004; Murray, 1999).

Celiac disease (CD) patients do not consume common bakery product such as baked food and allied food product especially those produced from wheat flour (Lovis, 2003; Moore et al., 2004). Celiac disease (CD) patient needs to avoid all such types of food contain protein gluten, originate in grain diet for example (oats, barley, wheat and rye) (Jnawali et al., 2016; Moreno et al., 2014). Unripe banana powder, on the other hand, has been investigated as a gluten-free substitute to wheat flour (Cureton and Fasano, 2009; Zandonadi et al., 2012). In celiac disease, where dietetic therapy is the only treatment, good nutrition shows an significant part in improving health (Jnawali et al., 2016; Rubio-Tapia et al., 2013).

2.10 Gluten-free Baked Products

Gluten is a structure-forming protein in flour that is responsible for the dough's elastic properties (Sapone et al., 2012). It adds in the form and crumb structure of a variety of baked goods. Glutenins and gliadins are the main protein found in the gluten which account for the elasticity and ensure viscosity of dough (Wang et al., 2017). Various non gluten items for sales are of substandard grade, texture, and flavor, as it has been claimed that removing gluten from bakeries causes major complications (Gallagher et al., 2004). According to Capriles and Arêas, (2014); Deora et al. (2014a, b); Korus et al. (2015a); O'Shea et al. (2014); Witczak et al. (2016) Starches, cereal, sorghum, millets, buckwheat, amaranth, quinoa, legumes, flaxseed, chestnut, rice, carob germ flour, and acorn are some of the most commonly used gluten-free raw materials. Dough prepared from gluten-free flour do not foam cohesive and elasticity compared to flour that contains gluten and it still industrial challenging as it's difficult to get raw material and ingredients exactly that can substitute wheat gluten (Pszczola, 2012; Wang et al., 2017). Baking with non gluten flour, on the other hand, yields bakery items a collapsing feel and low class (Segura and Rosell, 2011; Witczak et al., 2016). The finished baked product has a lower nutritional value than gluten baked items because of reduced amounts of substances for example: protein, vitamins, minerals, and dietary fibre (Gambuś, 2005; Handoyo et al., 2006; Lazaridou et al., 2007; Morita et al., 2006; Pastuszka et al., 2012; Segura and Rosell, 2011; Thompson, 2000; Witczak et al., 2016).

The growing figure of diagnosed victims who must follow a non gluten food is increasing demand for it (Sapone et al., 2012). Elimination of gluten-containing food to strictly gluten-free results in health improvement and has a significant effect on the gluten-free product sector (Giuberti and Gallo, 2018; Witczak et al., 2016). According to Nijeboer et al. (2013) approximately 20% of US consumer buy a gluten-free product. Table 5 shows selected studies on gluten-free (GF) product.

Table 5: Some investigation on gluten-free (GF) product. The effect of starch-related ingredients on properties of GF biscuit, cookies and cake.

Item	**Base starch/flour**	**Addictive starch/flour or other**	**Effect**	**References**
Cookies	Brown rice, corn starch	Buriti endocarp flour	Increase the amount of dietary fiber and minerals by up to 15% without affecting sensory qualities. Additional additions may result in unfavorable color and textural changes.	(Becker Fernanda Salamoni et al., 2014)
Cakes	Rice flour	Flour from chickpeas, peas, lentils and beans	The in vitro starch hydrolysis was somewhat modified in pea and lentil-containing cakes, providing a reduction in the estimated glycemic index (eGi), lentil flour resulted to low-density batters, higher specific volume, similar crumb hardness, and higher springiness than the control cake.	(Gularte et al., 2012)
Biscuit	Water chestnut powder, potato flour, analysis of different recipes and makhana powder	Analysis of different recipes	Biscuits were made with water chestnut powder and potato flour or makhana powder. The protein content of makhana powder biscuits is higher than that of potato flour biscuits. Mixtures containing 70:30 parts water chestnut and makhana powder produce the best sensory features.	(Mishra et al., 2015)
Cookies	Quinoa flour, flakes, corn starch	Improve the performance of a ternary mixture	Good sensory acceptance and a strong desire to buy	(Brito et al., 2015)
cookies	Rice flour, maize starch	Amaranth flours	Rise of ash, protein, lipids, and carbohydate. Functionality that looks promising	(de la Barca et al., 2010)

Table 5 adapted from: (Witczak et al., 2016)

2.11 Obesity and diabetes

According to Shaw et al. (2010), diabetes mellitus is one most common chronic diseases in approximately all countries, and it continues to grow in numbers and consequence, as changing lifestyle lead to reduce physical activity and increase obesity. According to Aggarwal et al. (2016), diabetics attack 382 thousands societies globally, with the amount likely to climb by 55 percent to 592 million by 2035. 175 million individuals with diabetes, however, are still undetected. High fat and sugar consumption has been linked to serious health issues and is one of the factors that contribute to obesity. Saturated fat consumption has been connected to elevated blood cholesterol and cardiovascular disease in some cancers (Aggarwal et al., 2016). Daily fat consumption accounts for around 40% of total caloric intake in the United States and Europe; though, well-being experts advise that it must not exceed 30% of whole calories in a food (Akoh and Casimir, 1998; Giese, 1996).

Since customers stand extra conscious in the link between food and wellbeing, the food industry has responded by adding low-fat, high-fiber, low-sugar and sugar-free foods to the market (Noronha et al., 2008; Winkelhausen et al., 2007). Despite these issues, fats and sugar are difficult to substitute particularly in bakery products (Zoulias et al., 2000). Sucrose is an essential ingredient in baking products because it adds volume, texture, and sweetness (Zoulias et al., 2000). However, due to the rising occurrence of illnesses such as obesity and diabetes, consumption of synthetic sugariness substitute as glucose replacement in the advance of light or natural foods has recently become a subject of research and development (Zoulias et al., 2000). Non sugar toffies, confenctions, and bubble gum, among other items, use polyols and other bulk sweeteners where the size, sucrose superiority and as sugariness are essential (Aggarwal et al., 2016).

Various research have looked into the effects of sugar substitutes such as maltitol, xylitol, mannitol, sorbitol, lactitol and glucose (Zoulias et al., 2000); steviol glycosides (Kulthe et al., 2014); sucralose and maltodextrin (Savitha et al., 2008); oligofructose and erythritol (Laguna et al., 2013); polyols, namely lactitol, sorbitol, and maltitol used to replace sugar-free cookies (Zoulias et al., 2002).

Fats provide flavour, mouth feels and they also contribute to the look, tastiness, quality and lubricity (Zoulias et al., 2002). Two of the most often utilized carbohydrate fat substitutes are maltodextrin and polydextrose (Zoulias et al., 2002). Presently, a wide range of carbohydrate-based fat replacer ingredients are used in bakery products to impersonate the special properties and qualities of fats, such as the use inulin to substitute fats (Rodríguez-García et al., 2013).

2.12 Xylitol and other Non-nutritive Sweeteners

Globally, xylitol is recognised due to its sweetness (Mäkinen, 1979; Winkelhausen et al., 2007). Xylitol provides only 2.4 kcal/g of energy, 40% fewer than that given by sucrose. As a result, xylitol is a healthy sugar replacement for low-energy foods (Emodi, 1978; Faria et al., 2002; Russo, 1977). Furthermore, because of its slow absorption and entry into metabolic pathways, xylitol is an essential sugar alternative for diabetics because it does not cause quick fluctuations in blood glucose levels (Pepper and Olinger, 1988; Rolla et al., 1987). The industry now offers a extensive selection of low-sugar and sugar-free foods and drinks, as well as low-energy foods and goods cooked with reduced energy, as a result of the strong market response (Abdullah and Cheng, 2001; Winkelhausen et al., 2007).

Strong sweeteners including cyclamate, thaumatin, aspartame, and aspartame are low-energy sweeteners that are applied in limited quantities in food items. However, bulk sweeteners, such as sorbitol, mannitol, lactitol, and xylitol, contain low energy per weight than sucrose despite having the same bulk volume (Bond and Dunning, 2006). At comparable applications, xylitol has a lower water activity than sucrose which helps a product's microbial stability and shelf life (Mushtag et al., 2010). Sugary items that can be applied to substitute sugar in baking can be classified based on its source (natural or artificial sweetener) the quantity of energy they contain (Bertorelli and Czarnowski-Hill, 1990; Levin et al., 1995; Patra et al., 2009). Table 6 shows sweeteners and their application in bakery products.

Table 6: Sweeteners and their application in bakery products

Sweetener	E-number	Relative sweetness (sucrose = 1)	Energy (kcal g^{-1})	Characteristics	Application in bakery product (references)
Xylitol	E 967	1	2.4	Cooling effect Flavour profile Very similar to sucrose	(Edelstein et al., 2007) (Ronda et al., 2005) (Sun et al., 2014) (Winkelhausen et al., 2007) (Zoulias et al., 2000)
Isomalt	E 953	0.45-0.6	2.0	Nonhygroscopic Odourless Mild sweetness without an aftertaste	(Edelstein et al., 2007) (Frye and Setser, 1992) (Martínez-Cervera et al., 2014)
Maltitol	E 965	0.8-0.9	3.0	Minor cooling effect Sensory and technical properties Similar to sucrose	(Edelstein et al., 2007) (Laguna et al., 2013) (Martínez-Cervera et al., 2014) (Psimouli and Oreopoulou, 2012) (Zoulias et al., 2002; Zoulias et al., 2000)
Lactitol	E 966	0.3-0.4	2.4	No after taste Less hygroscopic than sucrose Good solubility	(Frye and Setser, 1992) (Psimouli and Oreopoulou, 2012) (Zoulias et al., 2000) (Zoulias et al., 2002)
Mannitol	E 421	0.5	1.6	Non-hygroscopic, less soluble in water Chemically inert Able to mask a bitter taste	(Edelstein et al., 2007) (Psimouli and Oreopoulou, 2012) (Ronda et al., 2005) (Zoulias et al., 2000)

Table 6 adapted from: (Struck et al., 2014)

Table 6: (Continued): Sweeteners and their application in bakery products

Sweetener	E-number	Relative sweetness (sucrose = 1)	Energy (kcal g^{-1})	Characteristics	Application in bakery product (references)
Erythritol	E 968	0.6-0.8	0.2	Mild cooling effect Moderately soluble in water	(Laguna et al., 2013) (Lee et al., 2010) (Lin and Lee, 2005) (Lin et al., 2003) (Lin et al., 2010) (Martínez-Cervera et al., 2012) (Martínez-Cervera et al., 2014)
Sorbitol	E 420	0.5	2.4	Smooth mouthfeel Cool pleasant taste Hygroscopic, used as a humectant	(Baeva et al., 2003) (Frye and Setser, 1992) (kamel and Rasper, 1988) (Manisha et al., 2012) (Martínez-Cervera et al., 2014) (Psimouli and Oreopoulou, 2012) (Ronda et al., 2005) (Zoulias et al., 2000) (Zoulias et al., 2002)

Table 6 adapted from: (Struck et al., 2014)

CHAPTER 3: MATERIAL AND METHODS

3.1 Ethical Considerations

Ethical Clearance was granted before the research project commenced under ethical approval number 2017/CAES/162 UNISA Ethics Committee of the College of Agriculture and Environmental Sciences. There is no obvious ethical issue in this research.

3.2 Experimental sites and procedure

Full matured unripe banana fruit from ten selected cultivars (Khai Thong Ruang, Cavendish, Gold Finger, William, Lady Finger, Pisang Lemak, Grand Nain Cavendish, Fhia 18, Pome, and Chinese Cavendish) (figure 3) were harvested during April, May, June and July 2018 season from a gene bank block Agricultural Research Council – Tropical and Subtropical Crops (ARC-TSC) farm in Burgershall, Mpumalanga, South Africa (GPS, 25° 06' 30.53''S, 31° 58' 04.75'' E). The cultivars were selected based on their production yield. Thereafter, fruit were transported to the ARC-TSC drying and processing unit in Nelspruit (GPS, 25° 27' 04.8''S, 30° 58' 09.75'' E) for processing and analysis.

3.3 Experimental variables

Independent variables: The banana cultivar were the main independent variable in this research.

Dependent variables: The different test values obtained from the physico-chemical tests were dependent variables for the first phase. For the second phase, the hedonic scale sensory evaluation values of overall acceptability, colour, taste, flavour, and mouthfeel were the main independent variables.


Khai Thong Ruang
A
Cavendish
B
Gold Finger
C
William
D
Lady Finger
E
Pisang Lemak
F

Figure 3: Banana cultivars used in the experiment: (**A**) Khai Thong Ruang, (**B**) Cavendish, (**C**) Gold Finger, (**D**) William, (**E**) Lady Finger, (**F**) Pisang Lemak, (**G**) Grand Nain Cavendish, (**H**) Fhia 18, (**I**) Pome and (**J**) Chinese Cavendish.

3.4 Flour preparation

Preparation and processing commenced a day after harvest. Thereafter, the fruit was washed with clean tap water, peeled by hand, sliced into pieces of about 1 cm thick by means of a vegetable cutter machine (HLC 300), treated and preserved with sodium metabisulphite. Banana pieces were dehydrated at 50°C and 15% relative humidity (RH) about 15 hours using a hot-air forced fan dehydrator (AD 3000 Agri-Dryer, Dryer for Africa, South Africa). The resultant dried product was ground to powder using a Drotsky Miller (Drotsky Aktief (PTY) LTD Alberton, South Africa), thereafter, sieved through a 0.8 mm sieve subsequently, kept at ambient temperature (25°C) inside a closed plastic bag until further analysis. Table 7 shows flow chart of green banana flour preparation.

Table 7: Flow chart: green banana flour preparation

Unit operation	Comment
Receiving of banana	Green full matured banana wholesome
Sorting	Removal of disease, damaged and non-wholesome bananas
Washing	Wash with potable water to remove dirt, spray and other debris
Weighing	Measuring the weight of banana received using a calibrated balance
Peeling	Done manually using a knife
Preservation	Banana pulp was dipped into sodium metabisulphite solution
Slicing	Banana flesh was cut using a vegetable cutting machine
Pulp spreading	Sliced banana pulps were spread on drying trays
Drying	Banana slices were dried in an electric dehydrator
Cooling	Dried banana slices were allowed to cool after drying
Milling	Dried banana slices were milled using drotsky miller
Packaging	Milled banana flour was packaged in airtight sealed plastic for further analysis

Table 7 adapted from: (Ovando-Martinez et al., 2009)

3.5 Preparation of composite flour and particle size

Banana flour samples from 10 cultivars were sifted separately using 355µm serial no 139704 (Universal Laboratory Test Sieves). The sieve was shaken manually for five minutes. Samples of 200g sifted powder from each banana variety were mixed to make a composite flour. Composite flour kept on ambient temperature 25°C inside a closed plastic until further analysis. Figure 4 show universal test sieve 355µm and figure 5 show green banana flour composite.

Figure 4: Universal test sieve 355µm

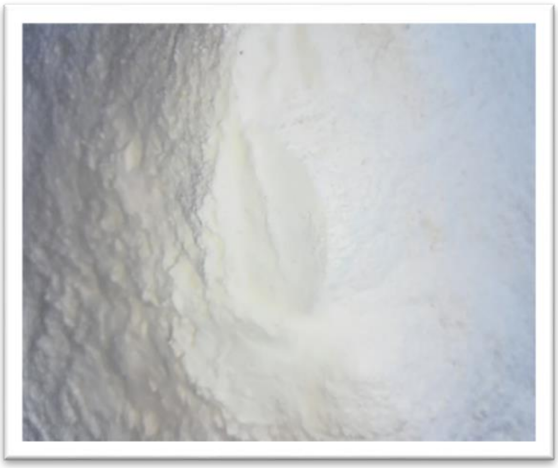


Figure 5: Green banana flour composite

3.6 Proximate analysis of composite flour

Moisture, Protein, Crude Fiber, and Ash were measured in banana flour composite. All sample measurements were done in triplicate. The source of chemical reagent that was used for protein content and crude fiber determination presented in Table 8. The methods used to prepare each solution are summarized in 3.6.1 to 3.6.4.

Table 8: Chemical reagents used in the determination of proximate analysis (crude fiber and protein content)

Chemical / reagent	Supplier/ source
Acetone	Merck (Pty) Ltd, Johannesburg, South Africa
Boric acid solution	Sigma-Aldrich agents in South Africa, Johannesburg
Methyl orange indicator	Sigma-Aldrich agents in South Africa, Johannesburg
Sodium hydroxide solution (NaOH)	Sigma-Aldrich agents in South Africa, Johannesburg
Hydrochloric acid (HCl).	Sigma-Aldrich agents in South Africa, Johannesburg
Selenium catalyst	Sigma-Aldrich agents in South Africa, Johannesburg
Sulphuric acid (H_2SO_4)	Sigma-Aldrich agents in South Africa, Johannesburg

3.6.1 Moisture content

The moisture content was measured by drying the samples in the oven for five hours at 105°C (AOAC, 2010). In a previously weighed crucible, approximately 2 g of finely ground banana composite flour powder was weighed. After cooling for 10 minutes, the samples were weighed and the % moisture content determined as follows:

Moisture % = $[(W_2 – W_3) / (W_2 - W_1)] \times 100$.

W_1 = Initial weight of empty crucible

W_2 = Weight of crucible + sample before drying

W_3 = final weight of crucible + sample after drying.

3.6.2 Ash

Ash was measured by dry combustion (AOAC, 2010). A 2g flour sample was weighed and transferred into a previously weighed crucible and placed into muffle furnace pre-heated 600°C for 8 hours. After that, the crucible was cooled and measured. The following formula was used to measure percent ash: percent Ash = [mass ash + crucible] – [mass crucible] / [mass food + crucible] – [mass crucible] – 100.

3.6.3 Protein content

The micro Kjeldahl technique was used to determine protein content (percentage N = 5.7) (AOAC, 2010).). In a heating tube, two grams (2g) of wheat samples were combined with 10 ml of concentrated sulphuric acid (H2SO4). A selenium catalyst tablet was added, and the mixture was heated in a fume closet. The digest was then transferred into a 100 ml volumetric flask and made up with distilled water. A portion of the digest (10 ml) was mixed with 10 ml 45% Sodium hydroxide solution (NaOH) and placed into a Kjeldahl distillation apparatus (Buchi Digestion and Distillation Protein Analyser, Switzerland). The mixture was distilled and the distillate collected into 4% boric acid solution containing 3 drops of methyl orange indicator. The distillate (50 ml) was collected and titrated using 0.1 M Hydrochloric acid (HCl). Percentage nitrogen was first calculated as: % N = [100 × W × N ×14 × Vf] × T / 100 × Va. W = Weight of the sample; N = Normality of the nitrate (0.1N), Vf = Total volume of the digest (100 ml), T = Titre value and Va = is the aliquot volume distilled. Percentage crude protein was calculated as % protein = % N * 6.25; where % N is the percentage nitrogen and 6.25 is the conversion factor.

3.6.4 Crude fibre

The amount of crude fiber was calculated using the procedure of (AOAC, 2010). Two grams (2g) of banana flour samples were weighed into a flask, which was then filled with 100 ml of 0.25 N Sulphuric acid (H2SO4). On the hot plate, the mixture was heated before filtered. 0.31 N sodium hydroxide solution (NaOH) was applied to the residue obtained and heated for 1 hour. The blend acquired was sieved by a fiber sifter fabric and 10 ml of acetone was added to it. The obtained residue was washed with hot water and transferred to a crucible. The crude fibre (%) was calculated as % crude fiber = Weight after drying / Weight of sample × 100.

3.7 Biscuit Formulation

Green banana flour composite from ten banana cultivars were used to substitute the commercial wheat flour (CWF). Biscuits were prepared according to commercial and bakery preparation with some modification (Rababah et al., 2006). For dough preparation, the concentrations of the main ingredients (flour, xylitol, shortening, milk) were varied between 5-55% w/w s; 1,12g baking powder; 1g fine grade coconut; 0,93g salt; 20g whole beaten egg and 2 drops banana essence was used. Dry ingredients were mixed using a mixture (Kenwood Chef, China) first, with the omission of shortening, completely beaten egg and fresh milk. Shortening was added and stirred until it was uniformly distributed. The eggs together wth milk were put in and combined in the mixture for 10 minutes. The dough was taken out from the mixture and allowed to break for 5 minutes.

The dough carefully pressed on a flat, clean stainless metal table at even thickness. The dough thinly rolled out up to uniform size and texture. Therefore, cut rounds using a biscuit cutter and baked in greased pan. The baking tests were conducted in an electric stove at 190°C for 20 minutes (KIC, South Africa). Baked samples was cool for 20 minutes and stored in plastics, heat-sealed using hand sealer and stored for further analysis. The concentration of the main ingredient presented in table 9-11, the source of ingredients that were used for biscuit production presented in table 12 and the flow chart of biscuit preparation presented in figure 6. Dough and biscuit prepared using 5%, 10%, 15% and 20% shortening, milk and xylitol presented in figure 7-9.

Table 9: Biscuit recipe prepared varying milk percentage

Milk%	**Shortening %**	**Xylitol %**	**Flour %**
5	20	20	55
10	20	20	50
15	20	20	45
20	20	20	40

Table 10: Biscuit recipe prepared varying shortening percentage

Shortening %	**Milk %**	**Xylitol%**	**Four %**
5	20	20	55
10	20	20	50
15	20	20	45
20	20	20	40

Table 11: Biscuit recipe prepared varying xylitol percentage

Xylitol%	**Shortening%**	**Milk%**	**Flour%**
5	20	20	55
10	20	20	50
15	20	20	45
20	20	20	40

Table 12: Ingredients utilized for the production of gluten-sugar-free banana flour based biscuit and their supplier

Ingredients	**Supplier**
Xylitol	Woolworth Food, South Africa
Milk	Spar, South Africa
Shortening	Spar, South Africa
Eggs	Spar, South Africa
Banana essence	Spar, South Africa
Salt	Spar, South Africa
Coconut	Spar, South Africa
Baking powder	Spar, South Africa

Weighing of Ingredients

↓

Mixing and sieving dry ingredients

↓

Mixing of dough using dough mixer

↓

Rolling and spreading of a dough into a sheet

↓

Cutting into round shape and placed on a baking tray

↓

Baking (190°C) 20minutes

↓

Removal of baked biscuit from the oven and cooled

↓

Packaging

Figure 6. Flow chart of biscuit preparation adapted from: (Yadav et al., 2012)

Figure 7: Dough and biscuits prepared using 5%, 10%, 15% and 20% shortening. (**A**) dough prepared with shortening 5%, (**B**) dough prepared with shortening 10%, (**C**) dough prepared with shortening 15%, (**D**) dough prepared with shortening 20%, (**E**) biscuit baked with shortening 5%, (**F**) biscuit baked with shortening 10%, (**G**) biscuit baked with shortening 15%, (**H**) biscuit baked with shortening 20%.

Figure 8: Dough and biscuits prepared using 5%, 10%, 15% and 20% milk. (**A**) dough prepared with milk 5%, (**B**) dough prepared with milk 10%, (**C**) dough prepared with milk 15%, (**D**) dough prepared with milk 20%, (**E**) biscuit baked with milk 5%, (**F**) biscuit baked with milk 10%, (**G**) biscuit baked with milk 15%, (**H**) biscuit baked with milk 20%.

Figure 9: Dough and biscuits prepared using 5%, 10%, 15% and 20% xylitol. (**A**) dough prepared with xylitol 5%, (**B**) dough prepared with xylitol 10%, (**C**) dough prepared with xylitol 15%, (**D**) dough prepared with xylitol 20%, (**E**) biscuit baked with xylitol 5%, (**F**) biscuit baked with xylitol 10%, (**G**) biscuit baked with xylitol 15%, (**H**) biscuit baked with xylitol 20%.

3.8 Biscuit physical analysis

3.8.1 Biscuit dimension

Total diameter (D) and thickness (T) of biscuit were measured in (mm) using 0 -200mm digital calliper. The analysis was done according to the method of the (AACC, 2011). To measure diameter, four biscuits were placed next to each other and re-measuring again in (mm) at triplicate. The biscuit was rotated at an angle of 90° and a new diameter was calculated. The average diameter of biscuit was the average of three readings divided by four. The thickness of the biscuit were set on by piling up four biscuits on top of each other and re-measuring again the thickness of four biscuits in (mm) at triplicate (Noor et al., 2012; Zoulias et al., 2002). The mean of three readings divided by four was the average thickness. Figure 10 show biscuit diameter and figure 11 show biscuit thickness.

Spread factors was calculated from diameter and thickness by the following equation:

$$SF= [(D/T) \times C.F \times 10], \quad (7)$$

Correction factors was taken to be 1.0 for adjusting D/T to constant atmospheric pressure

Equation adopted from: (Rababah et al., 2006)

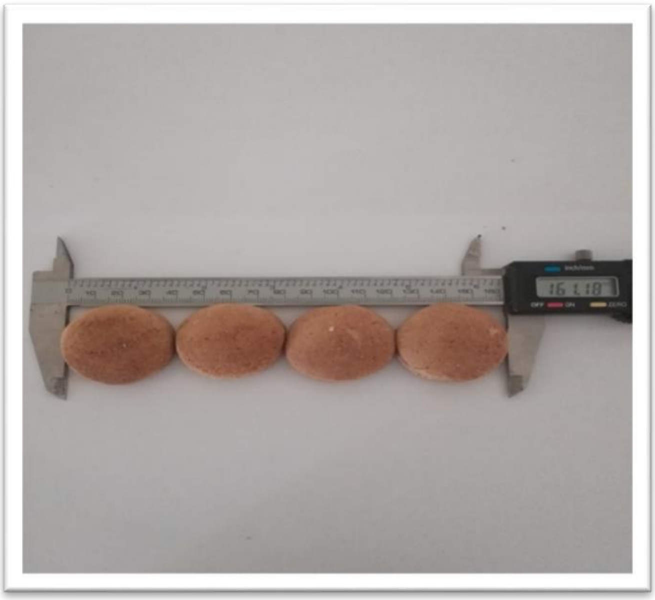


Figure 10: Biscuit diameter

Figure 11: Biscuit thickness

3.8.2 Browning index

The Browning Index (BI) was derived using the following equation (8), which was defined by (Buera et al., 1986).

$$BI = 100 \times \left(\frac{x - 0.31}{0.17}\right) \quad (8)$$

The x variables represents the chromatically coordinates calculated from L*a*b* values using equation (9).

$$\text{Where } X = \frac{(a* + 1.75L)a*}{(5.645L + a* - 3.012b)} \quad (9)$$

3.8.3 Dough and biscuit texture

The textural attributes of dough together with biscuits made with unripe banana flour composite were determined using texture profile analysis (double compression test). Texture profile analysis were done according to (Mamat and Hill, 2014). For this study, dough and biscuit firmness (stability, hard, soft and strength), adhesiveness (gumminess, stickiness, tackiness, glueyness) and modulus (elasticity, stretching, bending) were analysed. A texture analyser (TA-XT2 plus; Stable Micro Systems, UK) with exponent software were applied to assess the dough and biscuit texture. Dough texture was performed immediately after mixing and biscuit texture were performed an hour after baking. A measured rectangular dough sample (L x H x W) was cut, length was ranging between 30 - 32 cm, height between 9 -10 cm and width between 23 - 26 cm. Cylindrical biscuit samples were measured (H x D) in which diameter ranged between 40 - 45 cm and the height were in the range from 12 - 18 cm. Dough and biscuit samples were measured using a vernier calliper.

Before TPA commenced, texture analyser was calibrated. A measured rectangular dough sample and Cylindrical biscuit sample were placed on the texture analyser base and placed centrally under the probe. Probes were directly above the hole of the holed plate. The penetration test was started after the sample was deposited. Probe selection used for dough and biscuit penetration was P/2N. The tester was set at a test mode compression, test speed of 0,50mm/Sec, target mode distance of 2.0 mm, acquisition rate was 100 and typical test time was 150. A force-time graph of compression-decompression cycle characteristic was determined. Peak positive & negative force, peak positive & negative distance, positive area cycles and area to positive peak, Force at target and gradient to positive peak were analysed for the following: firmness, adhesiveness and modules. Dough measurements were replicated five times and biscuit measurement was replicated twenty-five times for each sample. The results are the mean values. Figure 12 show dough penetration analysis and figure 13 show biscuit penetration analysis.

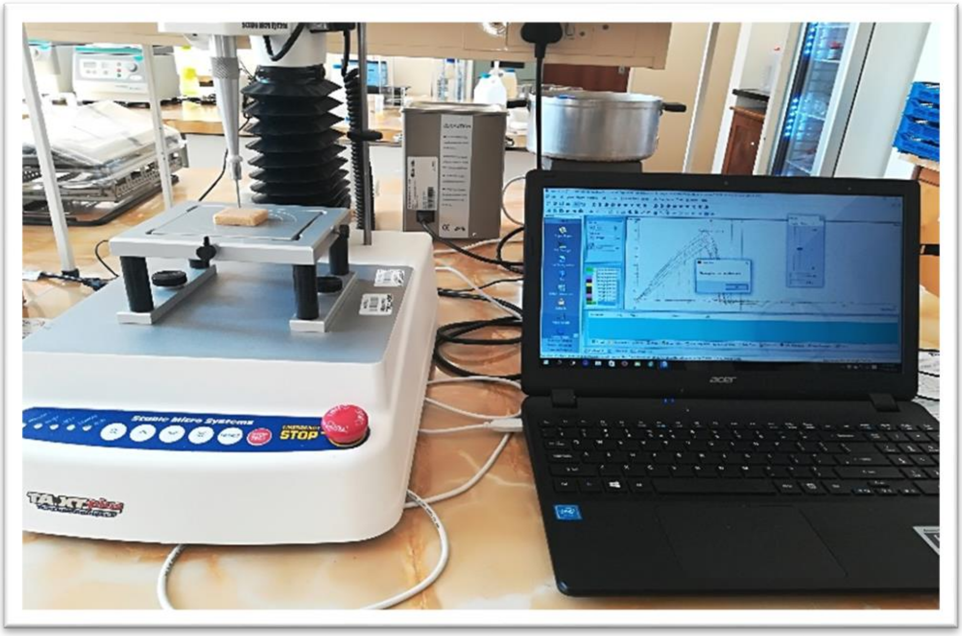


Figure 12: Dough penetration analysis

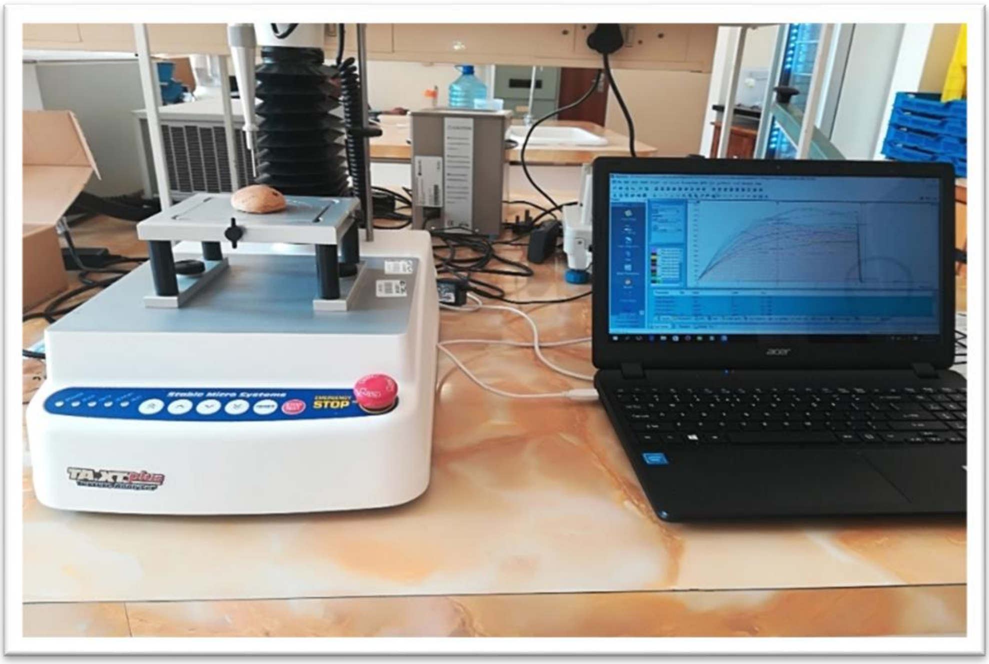


Figure 13: Biscuit penetration analysis

3.8.4 Consumer acceptability

According to Signham et al. (2015) distinct sensory assessment as approaches employed to suggest, quantify, examine as well as translate answers to outcomes seeming through senses of view, smell, touch, taste and hearing. Sensory qualities of gluten-sugar-free banana flour based biscuit were evaluated in terms of pigment, feel, palate and total acceptability. A 9-point hedonic scale from 1-dislike extremely, 2-dislike very much, 3- dislike very much, 4- dislike slightly, 5- neither like or dislike, 6- like slight, 7- like slightly, 8- like very much and 9- like very much were used to determine the colour, taste, mouthfeel, general acceptability, buy and not buy a sample. To evaluate gluten sugar free banana flour based biscuit, 120 untrained ARC-TSC personnel from Nelspruit, Freidenheim and Burghershall research farm in Mpumalanga province, South Africa, were used as a panellist to carry out the sensory evaluation. Numerous literature, as for the present studies, untrained panellist were used intended for sensory assessment (Błonska et al., 2014; Brito et al., 2015; Christensen and Vickers, 1981; Edmister and Vickers, 1985; Katz and Labuza, 1981; Laguna et al., 2013; Roudaut et al., 2002; Tarancón et al., 2013).

The panellists were comprised of different age group, male and female. Sensory evaluation measures were clarified to the panellist before testing began. Instruction on the sensory questionnaire and interpretation of the attributes were clarified to the panellist to avoid misunderstanding and they were given the chance to ask questions. The panellists were also given a consent form to sign in if there are willing to participate in the sensory assessment. Gluten – sugar – free banana flour based biscuit was baked a day before sensory evaluation. For each research farm, the sensory assessment was conducted on separate days. Each panellist received four biscuits to taste at the same time. Each biscuit sample presented to the panellist was in zip-lock polyethylene bags labelled with randomised alphabetic letters and were entered by the panellist into a score sheet. Between tasting panellists were given a slice of carrots to clean their mouth between the samples. The panellists were also requested to score if they would buy or not buy the sample.

The rating scores were as follows according to the questionnaire form

1. Sex: Male (1) and Female (2)
2. Age range: ≥20 (1), 20-30 (2), 30-40 (3), 40-50 (4), 50-60 (5), ≥60 (6)
3. Would you buy the sample: Yes (1) and No (2)
4. How often you buy biscuit or cookies? daily (1), Once a week (2), Once a month (3), Rarely buy (4) and Never (5)

3.9 Statistical analysis

Data were analyzed with SAS software, version 8.0 (SAS Institute, Cary, NC, USA), using one-way analyses of variance (ANOVA). Significance defined at $P<0.05$ by using Duncan's test. Statistical analysis was done by one-way ANOVA with SPSS version 23 (Institute Inc., Cary, N.C) statistical software. Duncan's Multiple Range Tests were used to investigate variances in mean at a 95% confidence interval. Correlation between the sensory attribute was assessed based on Spearman's Correlation rank. Three replications were done at all the tests.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Proximate analysis of green banana flour composite

According to Zakpaa et al. (2010) chemical composition is vital for the calculation of the nutritive quality of the food. Data on proximate composition of composite green banana flour results is shown in Table 13. The results showed that the flour moisture content was 9.95%±0.21 and was within the required limit for flours. According to Nasir et al. (2003), flour having 9% and 10% moisture content is more suitable for extended shelf life. Kongolo et al. (2017) reported low moisture content of the banana, wheat and maize ranged from (3.52% to 9.66%). Rayo et al. (2015) reported a low moisture content value range of between 2.61%±0.66 and 3.97%±0.49 in cavendish green banana flour produced by agglomeration process and Tribess et al. (2009) also reported low moisture content value range of between 1.6%±0.6 and 7.6%±0.4 in cavendish banana flour produced at different drying conditions in comparison to the present study. Moisture content of flour is the most significant factors regarding the flour quality (Gooding and Davies, 1997). Good storage stability of flour is achieved when the moisture content is low (Gooding and Davies, 1997).

The composite unripe banana flour, crude fiber was (1.62%±0.10), and was almost similar to that reported (1.7% of Monthana ABB and 1.8% Karpuravalli ABB) unripe banana flour (Selvamani et al., 2009). Yani et al. (2013) reported (1.90%) high crude fiber in Janten banana flour compared to the present study. However, Osundahunsi, (2009) reported low crude fiber content (1.30±0.12) of unripe plantain flour and Dame and Sahu, (2016) also reported low crude fiber in cavendish flour processed using different temperature levels, at 50 (0.5), 60 (0.43) and at 70 (0.4) compared to 50 ºC temperature of the present study. According to Chugh et al. (2013) eating of dietary fiber decreases the threat of cardiovascular diseases, constipation, appendicitis, colon cancer, diabetes mellitus and hemorrhoids.

The ash content of a present study was lower (2.42±0.02) than that of cavendish unripe banana flour (3.79%±0.01) indicated by Ramli et al. (2009) and that of matured plantain fruits (2.68±0.050) recorded by (Zakpaa et al., 2010). Pragati et al. (2014) also point out high ash content in unripe cavendish variety flour kept in different storage period, at 0 (3.53%), 20 (3.58%), 40 (3.67%) and 60 (3.75%). Ash of foodstuff, according to Zakpaa et al. (2010), is the inorganic content leftover left following the organic substance has been scorched away. As a result, ash content serves as a quality indicator for a product, as high amounts can indicate contamination (Zakpaa et al., 2010).

The protein content of the current investigation was higher (5.5%1±0.15) than that of Kepok Manado (2.80%) banana flour, Muli banana flour (2.55%) and Raja Nangka banana flour described by Thakur et al. (2016) and that of cavendish unripe flour(3.60±0.19) indicated by Menezes et al. (2011) as well as than that of unripe Prata (*Musa sapientum*) (4.57±0.35) recorded by (Batista et al., 2017). According to Zakpaa et al. (2010) protein content of foodstuffs is commonly done by the analysis of total nitrogen according to the methods of Kjeldahl. Total nitrogen is the sum of that derived from amino acids, which generally represent the vast majority, and that from non-protein nitrogen (NPN) sources, generally minor quality, existing in the foodstuff (Zakpaa et al., 2010). The amount of protein in the flour has a big impact on the rheological qualities of the dough (Payne et al., 1987; Wall, 1979). While flour protein content is critical to bread quality, gluten proteins are also crucial for bakers (Halverson and Zeleny, 1988).

Table 13: The proximate analysis results of composite flour moisture, protein, crude fibre and ash (%)

Proximate component	**Green banana flour**
Moisture (%)	9,95 ± 0,21
Protein (%)	5,51 ± 0,15
Crude fibre (%)	1,62 ± 0,10
Ash (%)	2,42 ± 0,02

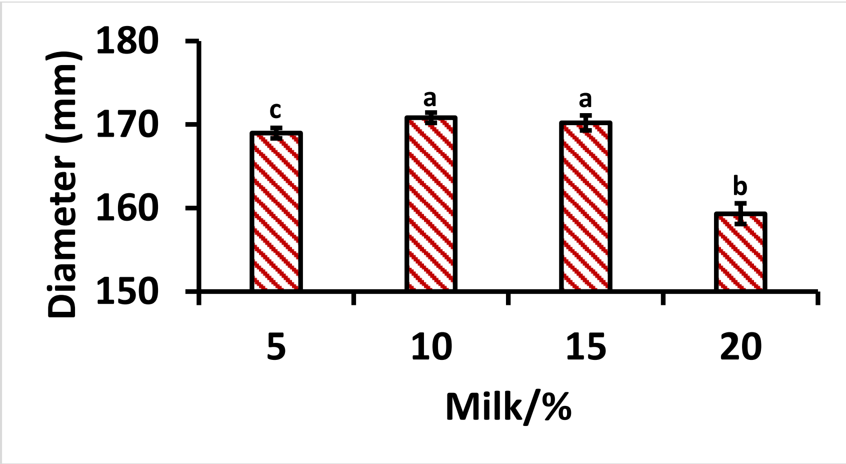
Mean value ± SD of three determinations

4.2 Biscuit dimension

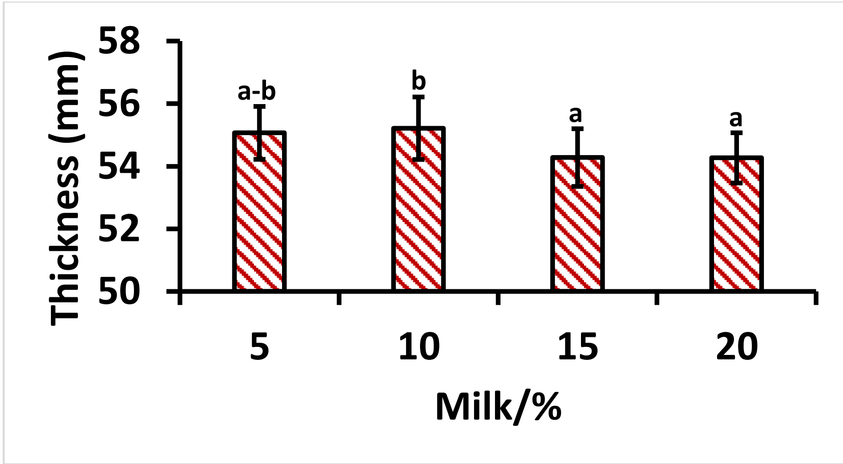
Figure 14 (A-C) shows the diameter, thickness and spread factor of biscuit baked varying levels of milk in the biscuit recipe. The diameter of biscuits made with 10 percent (170,82mm) and 15 percent (170,193mm) milk did not change considerably. The outcomes showed that 10% and 15% had higher diameter followed by 5% (168,972mm) while 20% (159,329 mm) showed the lowest diameter. Biscuit diameter significantly increases ($P<0.05$) with increase milk concentration, however, biscuit diameter showed significantly ($P<0.05$) decreases when more milk used in the recipe. According to the present results, a decrease of biscuit diameter when 20% of milk was used, affected the handling properties of biscuit dough adversely because of fluidity and adhesive of biscuit dough mixture. With 5% (55,066mm) and 10% (55,214mm) increase in milk, biscuit thickness rise considerably. Further increase of milk at 15% (54,277mm) to 20% (54,267mm) resulted in the reduction of biscuit thickness. Changes in diameter and thickness were also highlighted by the spread factor. The spread factor of all biscuits baked with varied milk concentrations differs considerably across the spread factor of all biscuit prepared varying milk concentration. When milk concentration increased from 5% (30,69mm) to 15% (31,36mm), there was a substantial rise in biscuit spread factor, and biscuit spread factor reduced when milk concentration increased to 20% (29,37mm).

Budžaki et al. (2014) result demonstrated dough formula without statistically significant alteration in the value of width and thickness between cookies of dry and wet formulae with increased moisture content. These findings were contrary, when compared to the results of current investigation. Maache-Rezzoug et al. (1998) similarly detected the rise in liquid amount with rise in total specific energy because additional moisture rises liquidity and stickness volume of the dough. Therefore, the dough coiled around the blending instrument blade during mixing, making the sheeting process difficult. The increase in fluids alters the dough's action after baking, resulting in a reduction in biscuit spread. Maache-Rezzoug et al. (1998) observations collaborated with those found in the present study whereby, biscuit spread of biscuit prepared with 20% (29,37mm) milk resulted in less spread factor compared to those prepared with 5% (30,69mm), 10% (30,95mm) and 15% (31,36mm) milk content, respectively. Mudgil et al. (2017) found a modest drop in spread ratio as water and partially hydrolyzed guar gum (PHGG) levels increased, which is in line with the findings of this investigation. With the current investigation, the dough prepared with milk at 20% was too elastic and viscous due to increased milk concentration, as a results biscuit showed reduced spread with low diameter and thickness during baking since the handling properties of biscuit dough was adversely affected by increase of milk. According to Jeltema et al. (1983), water soluble pentosans, pectin, water insoluble hemicelluloses, cellulose and lignin from wheat bran, oat bran, corn bran, navy bean hull and soy hull significantly lessen cookie expansion and softness. Hoseney et al. (1988); Hoseney and Roger, (1994) reported that cookies spread faster when the dough has a lower viscosity. Hoseney and Roger, (1994) also indicated that the concentration of water contained in the dough resulted in increased sugar melting during mixing, as a result, decreases the initial viscosity and cookie spread quicker during baking. Additionally, flour constituents that absorb a lot of water decreased the total of water that was present to melt sugar in the recipe. Therefore, commencing stickiness was more and the cookie expand slighter during baking (Hoseney and Roger, 1994). Kawai et al. (2013) found the decrease water action caused in a lesser expansion ratio of the cookie contrary to Faridi et al. (1994) stated that good cookie flour holds less water. As a result, slightly water absorption by flour improves sugar absorption, which increases syrup and reduces dough stickiness in the course of baking, allowing the dough to spread widely and produce huge cookie diameters (Slade and Levine, 1994).

A)



B)



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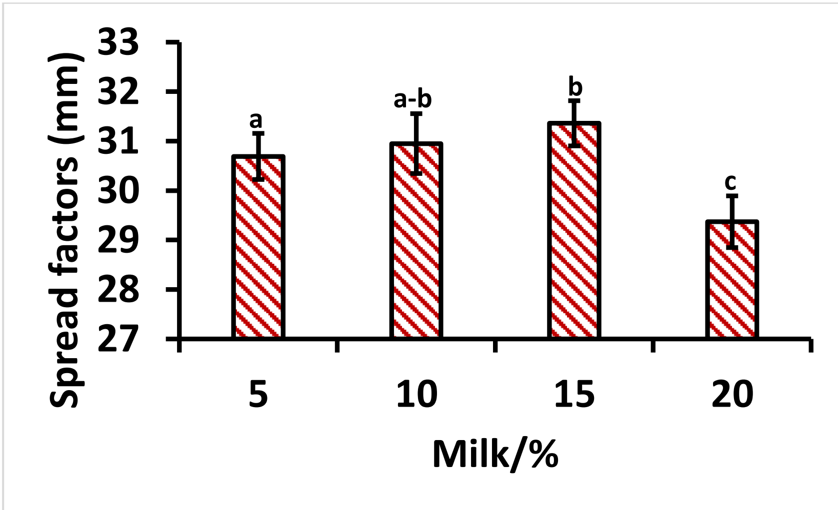


Figure 14: A-C Physical characteristics of biscuit prepared varying milk percentage

Figure 15 (A-C) shown the diameter, thickness and spread factors of biscuit baked varying shortening percentage in the biscuit recipe. Biscuit diameter prepared to vary shortening percentages showed drastically changes over entirely percentages. Biscuits prepared with 10% (167,749mm) shortening had higher diameter followed by 5% (166,583mm) shortening compared with 15% (164,381mm) and 20% (159,864mm). A further addition of shortening percentage at 20% significantly ($P<0.05$) affected biscuit diameter, therefore, biscuit dough mixture became fluidity and adhesive resulted in decrease of biscuit diameter. The thickness of biscuit prepared with shortening 5% (57,581mm) resulted in high mean value. The increase of shortening percentages resulted in decrease biscuit thickness. The thickness of biscuits made with 15% (54,329mm) and 20% (54,328mm) shortening, on the other hand, does not differ drastically. The spread factors drastically increased with rise in the concentration of shortening from 10% (30,24mm) to 15% (30,26mm) in biscuit. The spread factors rose drastically as the shortening concentration in biscuits increased from 10% (30,24mm) to 15% (30,26mm). Increase of shortening at 20% (29,43mm) resulted in a decrease in biscuit spread factors. Similarly, there was no drastically changes between biscuit spread factors prepared with shortening 5% (28,94mm) and 20% (29,94mm) and between 10% (30,24mm) and 15% (30,26mm). In the present study, biscuit prepared with 10% (30,24mm) and 15% (30,26mm) shortening showed superior biscuit than the ones prepared with shortening 5% (28,94mm) and 20% (29,94mm).

According to Barak et al. (2013); Kirssel and Prentice, (1979); Yamamoto et al. (1996) biscuit with a high spread ratio represents the best and better-anticipated quality parameter. Yamamoto et al. (1996) also indicated that large cookies diameter and huge spread are considered as the anticipated excellence features. According to Pareyt et al. (2008) oil content is a conclusive feature for the concluding assessment/quality of biscuits. The fats adds to cookie expansion and to overall cookie form and increases oxygenated for raise, size and make the cookies extra easly breakably (Maache-Rezzoug et al., 1998). According to Sudha et al. (2007) when fats are present in the dough, it becomes less elastic, which has an advantage in biscuit manufacture since it stops the dough from shrinking after sheeting. Consequently, reducing the fat level of biscuits during the preparation process results in a lesser biscuit spread with poor quality (Sudha et al., 2007). The outcomes of the present investigation are in line with Sudha et al. (2007), who found that lowering the fat content in the biscuit formulation lessen the spread factor. In the present studies, the spread factor reduced with reduce shortening and increased when shortening concentration was increased. Pareyt et al. (2009) highlighted that rise of fat amount in the course of baking is usually associated with a high spread ratio and more expansion degree, which can be attributed to the growth flexibility in the system as fats liquefy during baking, and the higher fat percentage leads to more oil point in baking. According to Rodríguez-García, (2013), biscuit size decreases as a fat replacement increase. Wehrle et al. (1999) showed that biscuit produced using butter had the highest thickness value, followed by margarine, however Na casein2 protein type (NaC2) fat powder produced the largest biscuits. Wehrle et al. (1999) also accentuate that although the process of sheeting, thickness and diameter was the same for all biscuits, the resulted thickness, diameter and spread factor of the final product varied. Seker et al. (2010) stated that one of the conclusive qualities of baked biscuit quality is the spreading out of the dough on the course of baking, which concludes the biscuit's dimension and feel.

In this study, less shortening content at 5% (28.94) resulted in the lower biscuit spread, whereas, 10% (30.24) and 15% (30.26) resulted in higher spread factor (Figure 16C). Maximum spread factor of biscuit occurred at 10% (30.24), thereafter 15%, at 20% (29.94)the spread factor slightly decrease. According to Baltsavias et al. (1997), biscuit dough prepared with liquid fats at room temperature yielded a delicate, difficult-to-handle dough. Jacob and Leelavathi, (2007) presented cookies made with sunflower oil had more spread rate, while cookies made with margarine and bakery fats had a similar spread value, however, cookie dough comprising hydrogenated fats spreads far less.

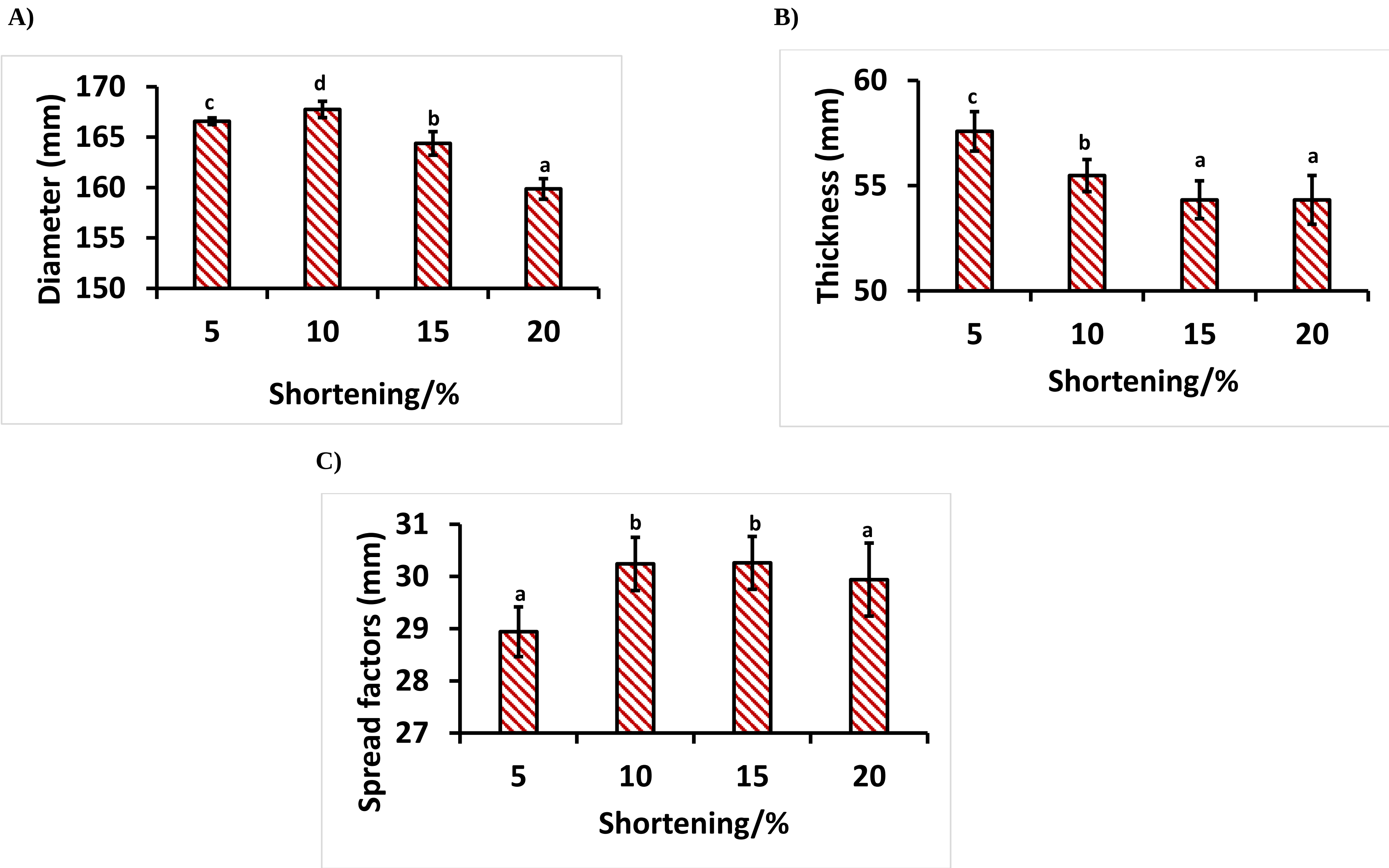


Figure 15: A-C Physical characteristics of biscuit prepared varying shortening percentage

Biscuit diameter, thickness and spread factors prepared with different concentrations of xylitol in the recipe are shown in Figure 16 (A-C). The findings indicated that biscuits made with xylitol 5% (164.61mm), 10% (165,344mm) and 15% (164,525mm) had no significant variation (P>0.05) in diameter, however, biscuit prepared with xylitol 10% (165,344mm) had higher diameter mean value than those prepared with 5% (164,61mm) and 15% (164,525mm) xylitol. Biscuits prepared with 20% (159,764mm) xylitol resulted in low diameter mean value. Varying xylitol concentration did not considerably alter the thickness of the biscuits (Figure 16B). The thickness of biscuit prepared with xylitol 5% had (54,786mm), 10% (54,909mm), 15% (54,367mm) and 20% (54,309mm) mean value. Biscuit prepared with xylitol 5% (30.05mm), 10% (30,11mm) and 15% (30,27mm) presented high spread factor and did not show statistical different (P<0.05). The result revealed that the spread factor increase from 5% (30.05mm), 10% (30,11mm) and 15% (30,27mm) with the increase xylitol concentration, however, a further increase to 20% (29,44mm) resulted at a significant (P>0.05) decrease biscuit spread as xylitol concentration resulted in the viscous dough and make sheeting difficult.

Zoulias et al. (2000) observed an increase in biscuit diameter with increasing sucrose content, however, with the present study increase in diameter was observed at 5% (164,61mm) and 10% (165,344mm) xylitol and biscuit diameter decrease was noted with a further increase of 15% 164,525mm) to 20% (159,764) xylitol. Laguna et al. (2013) noted a biscuit diameter decrease with sucrose reduction contrary with the present study. The present outcomes was compatable with Doescher et al. (1987) who observed an increase of final cookie diameter as the sucrose level increased up to 60% but at 75% concentration final diameter decrease. Manohar and Rao, (1997) also observed an increase of thickness with increasing sugar level. However, adding different type of sugars made a very slight difference in biscuit thickness. Manohar and Rao, (1997) results were in close agreement with the present study as increasing of xylitol percentage had a slight difference in biscuit thickness mean value. Taylor et al. (2008) results were also in close agreement with the present study were cookies created using 100% fructose was about the same height as cookies prepared using 100% sucrose. Handa et al. (2012); Taylor et al. (2008) highlighted that gluten growth contributes to the development of bakery items in expansion of baked goods, though cookies do not raise the intensity in height, since sucrose positively pull liquid over the gluten proteins. As a result, the volume and kind of sucrose used in recipes can have an influence on the height of biscuits According to Baljeet et al. (2010), the disparities in width and thickness increase and decrease are expressed in a spread ratio. Majzoobi et al. (2016) results found that when comparing date syrup and date liquid sugar as sucrose substitutes, the spread ratio increased with decreasing of sucrose content. Almana and Mahmound, (1991) observed similar results when sucrose substitution using invert sugar, liquid glucose, high fructose corn syrup. This findings are in contrary with the present study as the increase of xylitol from 5% (30,05mm) to 15% (30,27mm) increase biscuit spread, however further increase of xylitol at 20% (29,57mm) resulted in decrease spread factors. Laguna et al. (2013) showed that sucrose plays a significant part in biscuit development and final characteristics. According to Pareyt et al. (2009), dough consistency determine cookie expansion as well as cell size and cell wall distribution. Small amount of sucrose result in a lower cookie increase and, as a result, slighter average cell dimension (Pareyt et al., 2009). According to Handa et al. (2012), cookie spread arises as sugar melts during baking therefore undissolved sugar soften in the course of baking, this enables for a greater spread. The diameter-to-height ratio of cookies is known as cookie spread. As a results, the effects of sugar on the diameter (sugar dissolving) and height (gluten inhibition) are combined towards individual parameters (Taylor et al., 2008).

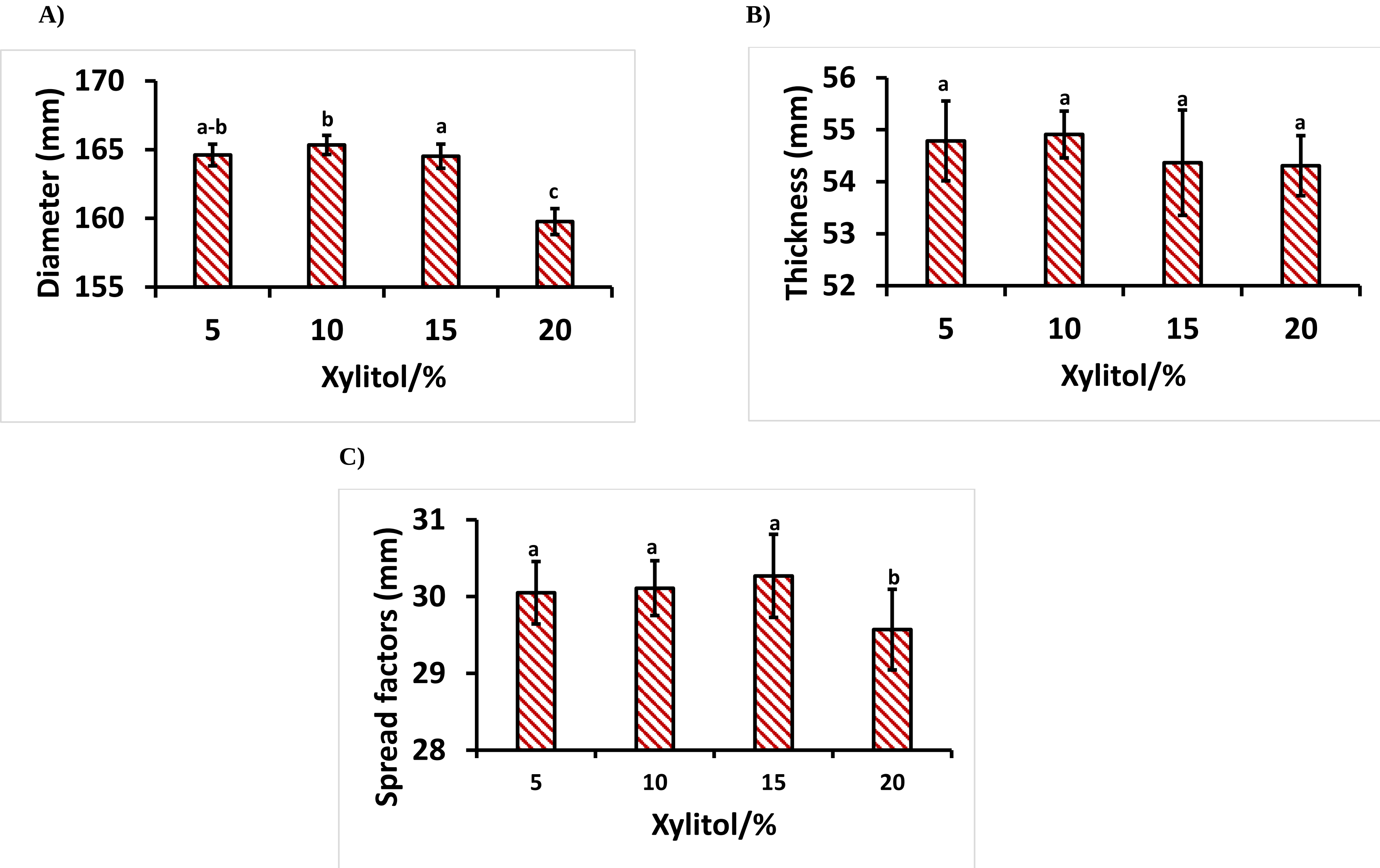


Figure 16: A-C Physical characteristics of biscuit prepared varying xylitol percentage

4.3 Browning index

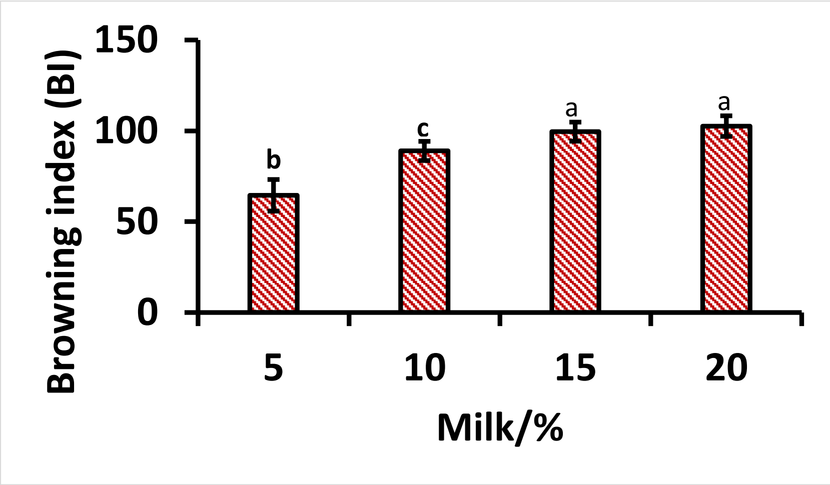
According to Quitão-Teixeira et al. (2007) browning index (BI) is a metric for describing how brown color varies over time. Buera et al. (1986) also defines browning index as one of the greatest shared markers of the browning in sugar containing nourishment. Changes of browning index of biscuit prepared to vary milk, shortening and xylitol percentage presented in figure 18: (A-C). The overall browning index of biscuits baked varying ingredient concentration drastically increased when ingredient concentration is increased. Biscuit baked varying shortening 5% (46.504), 10% (79.867), 15% (97.395) and 20% (102.591) and xylitol 5% (80.434), 10% (95.497), 15% (99.318) and 20% (103,178) exhibited a drastically alteration in browning index with the increase of ingredient percentage. On the other hand, browning index of biscuit baked varying milk percentage of 15% (99.548) and 20% (102.595) presented with no drastically change. Conversely, there is a significant difference in browning index of biscuit baked varying milk percentage of 5% (64.508) and 10% (88.944). According to Chandra et al. (2015) the biscuit's browning index is induced by Maillard reactions and caramelization of sucrose and amino acids, which can boost the baked product's antioxidant characteristics. Kawai et al. (2013) also stated that the Maillard reaction, which may be induced at high temperatures and with low water content, is primarily responsible for the browning of biscuits and baked goods.

The current investigation results reveal that lower milk content was linked to the low browning index in biscuit prepared with 5% (64.508), however, a drastically rise in browning index with an increased level of milk content was observed at 10% (88.944), 15% (99.548) and 20% (102.595). The findings of this study correspond with those of Leiva-Valenzuela et al. (2018) who found that biscuit browning is influenced by moisture content and composition. Zanoni et al. (1995) reported that the kinetic study is more multifaceted, as for baked products, maillard reactions and caramalization occur same time when a complex sugar and amino acid mixture is heated to a high temperature. Doporto et al. (2017); Hussain and Kaul, (2018); Mc Watters et al. (2003) demonstrated that cookie surface colour occurs due to non-enzymatic browning within reducing sugar and amino acids as well as from starch dextrinization and sugar caramelization. High mean value of browning index results observed with the increase of xylitol 5% (80.434) and 10% (95.497) than compared to biscuit prepared varying milk 5% (64.508), 10% (88.944) and shortening 5% (46.504), 10% (79.867) in the present study.

Hussain and Kaul, (2018) also observe that an increasing the amount of buckwheat flour used in baking increases the browning index. The same authors reported that the browning was also attributed to sucrose heating, as biscuits had excessive sucrose content. Ramirez-Jimenez et al. (2000) noted a considerable rise in browning index when bread is baked. Chandra et al. (2015) also stated that biscuit lightness is not only related to Maillard reactions in the course of baking still, as well with the flour color used, which might impact the biscuit's browning index. Consequently, with the current investigation, green banana flour used during preparation could influence the browning index of all biscuits samples.

Browning of biscuit on the surface during the final phase of baking is a common occurrence for biscuit during baking to conclude the baking course (Zanoni et al., 1995). According to Salem et al. (2019) results of biscuit prepared using different flours, rice, quinoa, amaranth and flour based samples browning index value were higher compared with the finding of the current investigation. Naknaen et al. (2016) found a notably rise in the non-enzymatic browning index as the watermelon rind waste (WRP) increased to higher levels in the cookie preparation, this result showed that the integration of either watermelon rind waste (WRP) or high-maize-starch (HMS) altered the non-enzymatic browning index of the cookie. However, Jan et al. (2015) results observe the opposite, as the amount of wheat flour in the mixes increases, the non-enzymatic browning index of the cookies drops, this could be owing to the carbohydrates and proteins in wheat flour being diluted by the addition of whole buckwheat flour. In this study, an increase of milk, shortening and xylitol at 20% resulted at the high browning index of all biscuits. At 20% browning index of all biscuits were almost similar, the reason for high browning might also be due to xylitol and shortening caramalization as formulated biscuit had high in xylitol and shortening content and were all-similar.

A)



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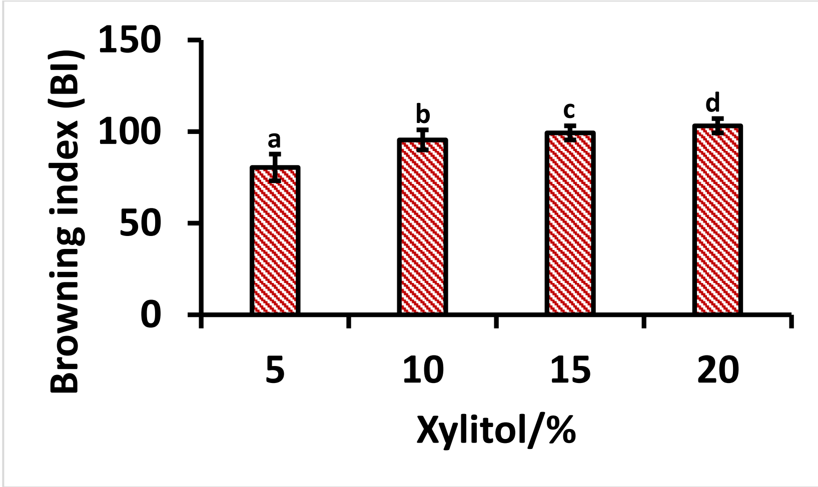

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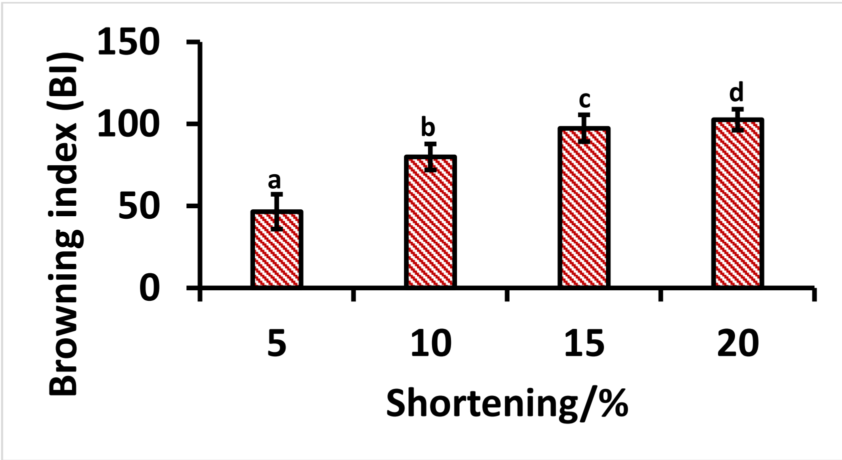

Figure 17: A-C Browning index of biscuit prepared varying milk, shortening and xylitol percentage

4.4 Texture

4.4.1 Dough textural properties

According to Chen and Opara, (2013) texture analysis provides direct figures on the product superiority and is an objective physical investigation of baked products contradictory to dough rheology tests as well as a report of baking appropriateness of the flour. Textural profile of dough sample prepared varying milk percentage is shown in Table 14. A notably decrease of dough sample firmness were detected when additional milk was added in the formula from 5% (82.21), 10% (24.73), 15% (15.45) and 20% (7.35). A significant ($P<0,05$) decrease of dough sample modulus were also detected when more milk was present in the recipe from 5% (266.54), 10% (66.28), 15% (35.15) and 20% (19.39). However, the increase of milk percentage from 5% (-3.84), 10% (-4.175), 15% (-4.434) and 20% (-4.038) did not statistically ($P<0,05$) change dough sample adhesiveness.

Maache-Rezzoug et al. (1998) showed similar results of decreased dough sample firmness and modulus when more fluid was contained in a recipe, when increasing water have control over a considerable drop in dough viscosity and a modest drop in relaxing time. Maache-Rezzoug et al. (1998) furthermore detected increases of the inconsistency and glueness volume of dough with excess water, of which is close with the results of dough sample adhensiveness of the present study. According to Navickis et al. (1982); Smith and Tschoegl, (1970) detected that when the water content is raised, elastic (G') and viscous (G") modulus was lessened. Létang, (1999) discovered that addition of water to the recipe have softening effects on the dough stability and viscidness. According to Maache-Rezzoug et al. (1998), when the amount of moisture in the dough is insufficient, the dough turn into stiff, inconsistent, and has a distinct "crust" result due to quick dryness on the top.

Table 14: Textural profile of dough prepared varying milk percentage

Treatment(/g) Milk content(/%)	Parameters		
	Firmness/g	Modulus/g	Adhesiveness/g
5	82,21 ± 10,53a	266,54 ± 39,27a	-3,84 ±1,26a
10	24,73 ± 2,01b	66,28 ± 7,4b	-4,175 ± 0,62a
15	15,45 ± 2,58c	35,15 ± 5,33c	-4,434 ± 0,49a
20	7,35 ± 1,02d	19,39 ± 1,98c	-4,038 ± 0,59a

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different ($P<0.05$)

Textural profile of dough sample prepared varying shortening percentage is shown Table 15. A substantial drop of dough sample firmness from 5% (119.878), 10% (32.945), 15% (13.638) and 20% (6.37) were noticed when more shortening was present in the recipe. A significant ($P<0,05$) drop of dough sample modulus were also detected when additional shortening was added in the formula from 5% (367.92), 10% (71.19), 15% (35.89) and 20% (14.91), Whereas, there is a substantial rise of dough sample adhesiveness after additional shortening added in dough sample. No substantial alteration among dough sample firmness 15% (13.638), 20% (6.37), modulus 15% (35.89), 20% (14.91) and adhesiveness at 15% (-3.809) and 20% (-4.205) detected.

The present results of dough sample firmness are similar to the outcomes to those published by Maache-Rezzoug et al. (1998); Sudha et al. (2007), who found that cookie dough develops firmer when less fats is used in its preparation. According to Mamat and Hill, (2014), fat is an significant element in baking foodstuffs and it performs a numerous of parts in delivering appropriate textural qualities. Fats are the primary elements in dough that help to bind the ingredients together. Chevallier et al. (2000) indicated that fats influence the increase of cookie dough during the course of baking by slowing the chemical inflate action, and also postulated that fats stabilize the cells in cookie dough. The nature and amount of fat applied to dough have a significant impact on its stickiness qualities (Baltsavias et al., 1997). Baltsavias et al. (1997) also found that lowering the fat level or replacing watery oil for the solid produced a noticeable reduction in the dough stiffness, implying that fat is the main structural element.

Miller, (1985) also stated that a higher fat content in short doughs softens the dough's consistency. Fat covers gluten and starch granules during dough formation to prevent them from adhering to one another, resulting in the creation of a soft, slimy, and processable stickiness dough shape (Jacob and Leelavathi, 2007).

Table 15: Textural profile of dough prepared varying shortening percentage

Treatment(/g) Shortening content(/%)	**Parameters**		
	Firmness/g	**Modulus/g**	**Adhesiveness/g**
5	119,878 ± 22,43a	367,92 ± 78,61a	-0,838 ± 0,54a
10	32,945 ± 3,13b	71,19 ± 5,92a	-2,483 ± 0,69b
15	13,638 ± 0,87c	35,89 ± 2,96bc	-3,809 ± 0,68bc
20	6,37 ± 0,58c	14,91 ± 1,07c	-4,205 ± 0,58c

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different (P<0.05)

Textural profile of dough sample prepared varying xylitol percentage is shown in Table 16. The firmness of dough sample prepared varying xylitol percentage substantial drops with the rise of xylitol percentage from 5% (50.37), 10% (25.59), 15% (13.27) and 20% (10.88). Modulus of dough sample also decrease with increase xylitol percentage from 5% (367.92), 10% (71.19), 15 (35.89) and 20% (14.19) however, at 15% (35.89) and 20% (14.91) did not statistically (P<0.05) alter dough sample modulus. The increase of xylitol percentage from 5% (-0.838), 10% (-2.483), 15% (-3.809) and 20% (-4.205) did not alter adhesiveness of the dough sample.

The decreases of dough sample firmness with increases of xylitol percentage of present outcomes are equivalent to those stated by Pareyt et al. (2009) stated that with increase sugar levels biscuit dough hardness decreases. Maache-Rezzoug et al. (1998); Manohar and Rao, (1997) also reported that when more sugar was added, cookie dough firmness decrease. Therefore, when more sucrose present on biscuit dough, the dough became watery structure as a separately gram of sugar melted per gram of liquid rises the solvent content (Hoseney, 1994).

The present results of dough sample adhesiveness are close with Manohar and Rao, (1997) finding observed increases of dough adhesiveness and stickness when sugar levels increased. According to Manohar and Rao, (1997), sugar is a significant constituent of biscuit dough, it gives feel, flavour, sugariness in biscuits. Manohar and Rao, (1997) also reported sugar concentration in biscuit dough influences several rheological parameters including stability and firmness.

Table 16: Textural profile of dough prepared varying xylitol percentage

Treatment(/g) Xylitol content(/%)	**Parameters**		
	Firmness/g	**Modulus/g**	**Adhesiveness/g**
5	50,37 ± 2,72a	152,33 ± 12,19a	-4,16 ± 1,32a
10	25,59 ± 1,6b	66,57 ± 3,15b	-5,15 ± 0,86a
15	13,27 ± 1,26c	31,14 ± 2,24c	-4,62 ± 0,67a
20	10,88 ± 0,99d	26,90 ± 1,49c	-4,66 ± 0,7a

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different ($P<0.05$)

According to Mamat and Hill, (2014) the physical attribute of dough is significant because they influence how the dough is handled and processed, together with the superiority of the ultimate diets. Dough firmness is computed by means of negative force area acquired from the initial compression phase, which represents the labor required to draw the compressing plunger away from the tester (Yamul and Lupano, 2003).

In this study, dough sample firmness varied significantly ($P<0.05$) across ingredients used. It can be observed that ingredients at high percentage 20% had the lowest dough firmness compared to ingredients at lower percentage 5%. A similar trend was also observed for dough sample modulus across all ingredients used during dough preparation. No substantial alteration detected on adhesiveness of dough sample prepared varying milk and xylitol percentage. According to Emami et al. (2018) studies, states that biscuit dough textural properties are significant as they determine the quality of biscuit. The study agrees with Wade, (1988) reported that strong or watery dough will not froth appropriately on the dough foaming device, resulting in undesirable biscuit.

For the present study, the increase of dough softness with an increase of ingredient percentage was observed, however, firmness and modulus at 10%, 15% of milk, shortening and xylitol resulted in stable dough sample that are easy to make a sheet. Srivastava et al. (2010) study emphasizes that the stickiness of the dough is important for sheeting of dough biscuits. Based on the present results, dough sample made from 5% milk (82.21), shortening (119.878) and xylitol (50.37) resulted in a firm dough sample and dough sample made with 10% milk (24.73), shortening (32.945), xylitol (25.59) and 15% milk (15.45), shortening (13.638), xylitol (13.27) resulted in a stable sheeted dough however, the dough made from 20% milk (7.35), shortening (6.37) and xylitol (10.88) resulted in a too soft dough sample. Further increment in ingredient percentage and lowering of banana flour percentage had an effect on dough sample. These results showed that unripe composite banana flour percentage also has significant part in the development of dough sample construction during preparation in relations to firmness, modulus and adhesiveness. A similar trend was detected by Ajila et al. (2008) found that as the amount of mango peel flour substituted increased, the hardness of soft dough biscuits increased. According to Norhidayah et al. (2014), replacing various kinds of banana flour resulted in various impact on the toughness of the cookies. Cookie made of 50% Tanduk unripe banana flour had highest firmness than cookie made of 50% Emas unripe banana flour (Norhidayah et al., 2014).

4.4.2 Biscuit textural properties

One of the biscuit's most distinguishing traits is its quality (Mamat and Hill, 2014). The quality and texture of biscuits is determined by the preparation method employed Kulthe et al. (2014); Maache-Rezzoug et al. (1998), and can be interpreted in a state of their principal ingredient. Table 17 presents the textural profile of biscuit sample prepared varying milk percentage. The firmness of biscuit sample prepared varying milk percentage notably drops when milk percentage increases from 5% (617.80), 10% (315.73), 15% (266.48) and 20% (191.56). A significant ($P<0,05$) decrease of biscuit sample modulus were also observed when more milk was added in the recipe from 5% (466.14), 10% (179.25), 15% (141.22) and 20% (68.58). The results of this test showed that biscuit sample prepared with milk 5% (617.80) were significantly ($P<0.05$) firm and difficult to cut than biscuit prepared with 10% (315.73), 15% (266.48) and 20% (191.56) milk. Biscuit sample modulus also showed that milk 5% (466.14) had significantly higher mean values compared with 10% (179.25), 15% (141.22) and 20%

(68.58) milk. The observation of adhesiveness presented a substantial alteration amongst 5% (-1.6305) and 10% (-0.9234) milk, however no substantial variation amongst 15% (-1.2381) and 20% (-1.3363) milk detected.

The results of biscuit samples firmness, modulus and adhesiveness of the current study are in agreement with Norhidayah et al. (2014) findings indicated that the total volume of liquid used in the formulation of the biscuit affects the structure of resulted biscuits. Maache-Rezzoug et al. (1998) also found that the amount of water in the dough impacts its behavior later baking. Mudgil et al. (2017) findings after regression study presented the differences in partially hydrolyzed guar gum (PHGG) stages and baking time where shown to be directly related to cookie hardness, whilst liquid amount in cookie dough oppositely influenced the cookie hardness. From the present study biscuit sample firmness and modulus decreases observed when more milk was added in the recipe.

Table 17: Textural profile of biscuit prepared varying milk percentage

Treatment(/g) Milk content(/%)	**Parameters**		
	Firmness/g	**Modulus/g**	**Adhesiveness/g**
5	617,8 ± 91,86a	446,14 ± 115,27a	-1,6305 ± 1,51b
10	315,73 ± 47,81b	179,25 ± 40,87b	-0,9234 ± 0,51a
15	266,48 ± 46,92c	141,22 ± 38,34c	-1,2381 ± 0,69ab
20	191,56 ± 34,64d	68,58 ± 19,84d	-1,3363 ± 0,9ab

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different (P<0.05)

Table 18 presents the textural parameters of biscuit sample prepared varying shortening percentage. It can be observed that the increases of shortening from 5% (403.46), 10% (283.90), 15% (248.41) and 20% (214.25) percentage significantly (P<0.05) decreases biscuit sample firmness. A significant (P<0.05) increases of biscuit sample modulus were observed when more shortening percentage increased between 5% (103.25) and 10% (140.04). No statistical substantial different detected between biscuit modulus formulated with 15% (85.89) and 20% (67.57) shortening. Substantial different was not detected in biscuit adhesiveness prepared using 5% (-3.2381) and 10% (-2.8508) shortening. The same trend were observed on biscuit adhesiveness prepared with 15% (-1.8286) and 20% (-1.2556) shortening.

The results of biscuit firmness sample of the current investigation are in line with those of Sudha et al. (2007), stated that fats reduction lead to a hardness in biscuits and highly correlated to hardness of biscuit dough. Laguna et al. (2012) also noted that the increased lipids content, the gooey the biscuit becomes. Maache-Rezzoug et al. (1998) confirmed similar findings, stating that the more the fat amount, the more friable the structure and easy to break of biscuit after baking. According to Zoulias et al. (2002a), lowering the fat level or replacing with various component for fat carries a significant influence on the textural qualities of biscuits. In addition, Lai and Lin, (2006) also observed that the more the fat concentration the more cookie softness increases. According to Pareyt et al. (2010), lowering fat concentration resulted in higher cookie breaking strength. Chin, (2016) stated that fats act as emollient and gives cookie softness texture. Jacob and Leelavathi, (2007) stated that fats averts extreme expansion of gluten proteins in the course of mixing. Given, (1994) stated that fats are applied in biscuit manufacture to share and grap air combined in the course of emulsifying stage resulting in a crisp product. From the present study, shortening percentage variation added during baking had a strong effect on the firmness, modulus and adhesiveness of biscuit texture

Table 18: Textural profile of biscuit prepared varying shortening percentage

Treatment(/g) Shortening content(/%)	**Parameters**		
	Firmness/g	**Modulus/g**	**Adhesiveness/g**
5	403,46 ± 41,43a	103,25 ± 13,13b	-3,2381 ± 2,27b
10	283,9 ± 47,74b	140,04 ± 62,02a	-2,8508 ± 1,53b
15	248,41 ± 41,81c	85,89 ± 32,37bc	-1,8286 ± 0,86a
20	214,25 ± 31,59d	67,57 ± 13,18c	-1,2556 ± 0,80a

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different ($P<0.05$)

Table 19 presents the textural parameter of biscuit prepared varying xylitol percentage. There was significant (P<0.05) different between 5% (864.72), 10% (358.75) firmness of biscuit sample baked varying xylitol percentage. However, there was no signigicant (P>0.05) different with an increases of xylitol percentage at 15% (258.05) and 20% (278.28) of biscuit sample firmness. It can be clearly observed that biscuit firmness sample prepared with 5% (864.72) xylitol are firmer than biscuit sample baked with 10% (358.75), 15% (258.05) and 20% (278.28). Substantial different was detected of biscuit sample modulus baked varying xylitol 5% (592.3) and 10% (162.49). However, there was no signigicant (P>0.05) different of biscuit sample modulus baked varying xylitol percentage at 15% (108.51) and 20% (97.67). Biscuits sample modulus also decreases with the increases of xylitol percentage. Biscuit adhesiveness data results showed no significant (P>0.05) alteration due to xylitol percentage.

The firmness outcomes of current research agreed with Mushtag et al. (2010) studies stated that cookie made with 100% xylitol resulted in softer cookies, which means increased xylitol percentage during preparation resulted is soft biscuit. Taylor et al. (2008) indicated that the firmness of the cookies linked with expansion of the gluten network, forming the cookie shape. Gluten must network with liquid particles to facilitate network growth; however, sugar obstructs this by drawing water preferentially. Sugars may crystallize after the baked cookies cool, adding to the cookie's firmness (Taylor et al., 2008). Maache-Rezzoug et al. (1998) noted that cookie contain too much sugar have a high hard form and a crunchy feel. And, they also discovered that adding of sucrose lead to a fall in the stickiness consequently increased sucrose ease the dough because of its physical-chemical part related to liquid and thickener.

According to Curley and Hoseney, (1984) gumminess is linked with the volume of sucrose that melts before baking, when sucrose liquefies, it affects the rise of full mixture mass within a dough. The outcomes of the current investigation adhesiveness indicated that the use of xylitol and banana flour did not have an influence on the texture of resulted biscuit sample. Laguna et al. (2012) indicated that the lack of sugar in cookies has a negative effect since it rises the gluten network, which gives the dough and cookies flexibility.

Table 19: Textural profile of biscuit prepared varying xylitol percentage

Treatment(/g) xylitol content(/%)	Parameters		
	Firmness/g	**Modulus/g**	**Adhesiveness/g**
5	864,72 ± 149,52a	592,3 ± 96,46a	-1,2254 ± 0,68a
10	358,75 ± 67,55b	162,49 ± 63,1b	-1,2476 ± 1,08a
15	258,05 ± 59,36c	108,51 ± 45,18c	-1,775 ± 1,28a
20	278,28 ± 68,92c	97,67 ± 45,8c	-1,5033 ± 1,08a

The figures represent the average of three determinations. The means in each column with the same letter are not substantially different ($P<0.05$)

Texture analysis is an appropriate analytic process to relate bakery product (Sipos et al., 2008). For determination of food texture properties, compression and puncture test are the best common methods (Chen and Opara, 2013). Generally, parameters perceived for evaluation of sensory quality and rheological properties of a number of foods in the textural profile analysis are hardened, adhesiveness and cohesiveness (Friedman et al., 1963; Nishinari et al., 2013). In the current investigation, biscuit sample firmness prepared varying milk and shortening percentage was significantly ($P<0.05$) varied across ingerdients percentage. However, biscuit sample prepared with 5% xylitol firmness (864.72), modulus (592.3) had high mean value compared with 5% milk firmness (617.8), modulus (446.14) and 5% shortening firmness (403.46), modulus (446.14). Pareyt et al. (2009) stated that cookie had a lot of sucrose and fat content while also having a low water content of (1-5 percent).

According to Manisha et al. (2012), cookies made with sugar-free or less sucrose, results in lack of consistency, poor aeration and cell foam. This findings are in close agreement with the firmness, modulus and adhesiveness of biscuits prepared varying xylitol percentage of the present study. During rich tea - type biscuit, Brown and Braxton, (2000) stated that biscuit must be soft enough to get the anticipated crumbly texture but at the same time rather or slightly hard in order to be seeming as crunchy. Pareyt et al. (2010) stated that lipids have a considerable influence on the firmness of pastry items, for this reason, compared with present study, the increase of shortening percentage resulted in the decreases of firmness and modulus of biscuit sample. Sudha et al. (2007) also found that when the fat level in the biscuit preparation was less, the firmness of the biscuit dough rise in the texture analyser. Similar trend of decreases biscuit sample firmness and modulus was observed with increase of milk percentage during preparation of biscuit sample.

The observation of biscuit texture firmness, modulus and adhensiveness of the current investigation were very similar with those reported by researchers of cake and biscuits produced incorporated with different flour percentages. Norhidayah et al. (2014) compared the firmness of biscuits made with different flour percentages of Tanduk banana flour (TBF), Emas banana flour (EBF), and control at varied percentages, and found that Tanduk banana flour (TBF) incorporated cookies had higher hardness than control cookies. (Ajila et al. 2008) discovered the similar tendency, with soft dough biscuit hardness increasing as mango peel flour replacement increased. The dough is transformed into a cellular compact during the baking process (Pareyt and Delcour, 2008). Protein denaturation, starch gelatinization, fat melting, Maillard reactions, water loss, and gas production and thermal expansion are all examples of diverse biochemical and physicochemical events (Chevallier et al., 2002).

4.5 Consumer acceptability

In the present studies, 28.6% of judges were between the ages of (20-30); 26.9% (30-40); 18.5% (50-60); followed by 20 and >60 with less number of judges. In these evaluation, different age groups, 50. 9% buy biscuits once a month; 27. 6% once a week; 13.8% rarely buy, and 3.4% never buy biscuits. The results showed that majority of consumer (50.9%) buys biscuit once a month. Laguna et al. (2011) indicated that 100 untrained regular short dough cookie buyers aged from 18 up to 65 years contributed in the testing assessment of reduced-fat short dough biscuits. Numerous literature, as for the present studies, untrained panellist were used for sensory evaluation (Brito et al., 2015; Christensen and Vickers, 1981; Edmister and Vickers, 1985; Katz and Labuza, 1981; Laguna et al., 2011, Roudaut et al., 2002). In the current study, gluten-sugar-free banana flour based biscuit without incorporation with other crops flour and where xylitol is used to substitute sucrose is new therefore, the sensory evaluation will help to regulate the consumer preference that will incentive gluten-sugar-free banana flour based biscuit acceptability and purchasing committed.

Sensory assessment is a crucial constituent of product development (Winkelhausen et al., 2007).   The incorporation of the customer's observations of pigment, feel, and flavor into an general feeling of the superiority determines ether items for consumption is acknowledged or rejected (Winkelhausen et al., 2007). The sensory assessment measured is a crucial instrument in defining consumer acceptability and is considered a valuable tool in determining consumer acceptability of innovative products (Emami et al., 2018). Sensory assessment of items also guides manufacturer or goods innovator groups on what to modify to match the consumers by replacing or substituting the ingredients (Moussaoui and Varela, 2010). According to Civille and Oftedal. (2012), sensory assessment is decribed as a scientific subject that includes all methods for eliciting, measuring, analyzing, and interpreting individual reactions to the qualities of food material as experienced by the five senses: taste, aroma, trace, vision, and hearing. Sensual assessment testing is costly and laborious since consumer are asked to check only one item for the outcomes to be significant (Signham et al., 2015). The only judge of the acceptability of food is consumed and gives a judgment of the overall acceptability. Due to the diversity of human reactions and sentiments, the sensory test yields diverse findings (Signham et al., 2015). Different age groups participated in sensory assessment shown in figure 18, the consumption frequency of panellist in figure 19 and sensory evaluation sample order in figure 20.

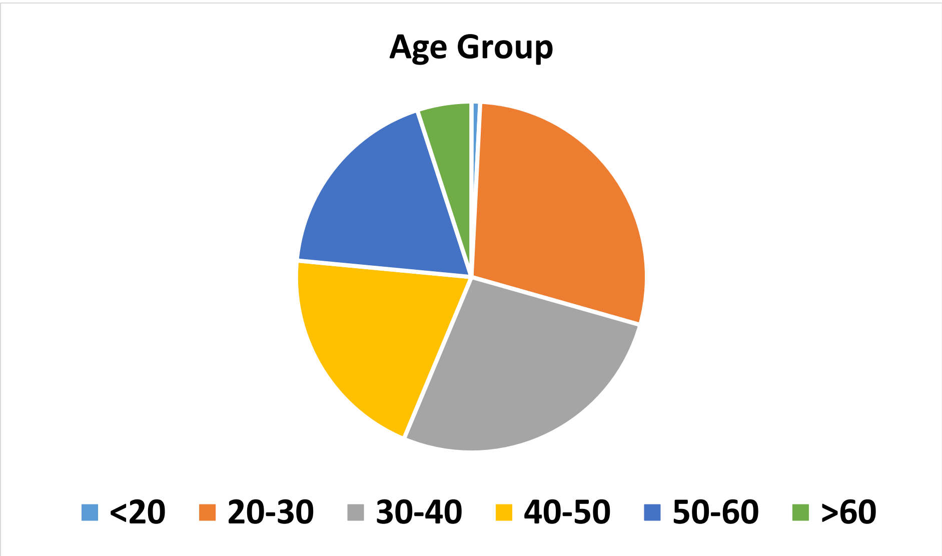

Figure 18: Different age group participated in sensory evaluation

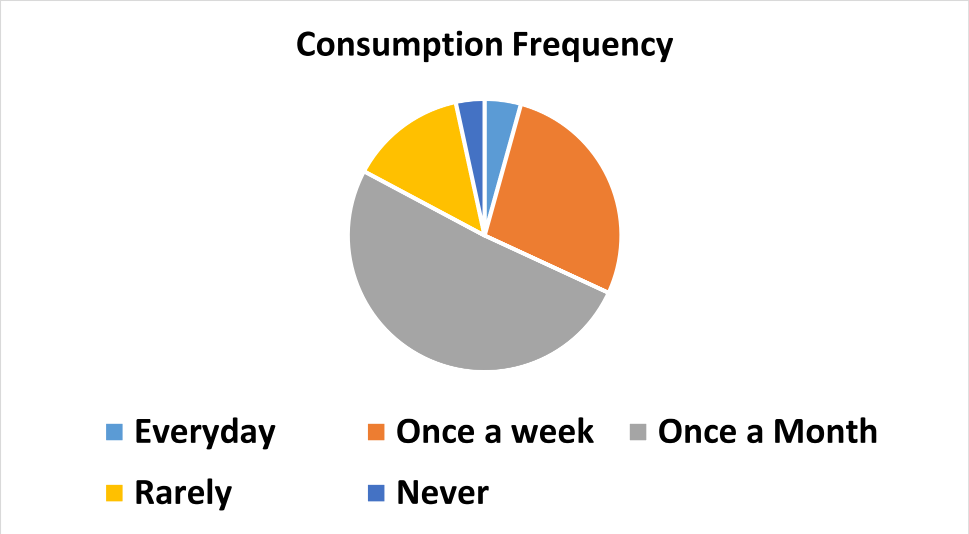

Figure 19: Biscuit Consumption Frequency of the panellist

Figure 20: Sensory evaluation sample order

4.5.1 Correlation between treatment and sensory evaluation factors

The Spearman rank correlation coefficient is a non-parametric method for calculating the degree of correlation among two independent variables and the circulation of the population does not affect it (Gauthier, 2001). Correlations between parameters were done using Spearman's correlation coefficient shown in Table 20. Overall acceptability was most significantly ($P< 0.05$) correlated with taste (r=0. 95) and texture (r=0. 95). This is recommended that taste and texture were crucial drivers of liking for the customers assessing biscuits. The willingness-to-buy was moderately correlated with taste (r=0.60) and texture (r=60). Negative correlations were found between taste (-0.14), texture (-0.12), overall acceptability (-0.12), and willingness to buy (-0.12) of biscuit prepared varying milk concentration. In particular, taste (0.25), texture (0.22), overall acceptability (0.23), and willingness to buy (0.15) of biscuit prepared varying shortening concentration showed a greater drop in all parameters than biscuit prepared varying xylitol concentration. In this study, milk, shortening and xylitol showed low correlations with the organoleptic properties.

The present result shows that consumer overall acceptability was more likely to like the taste and texture of biscuit, however willing to buy was moderate to like gluten-sugar-free banana flour based biscuit. Similarly, Laguna et al. (2011) found that consumer texture and taste on low-fat short-dough biscuits were substantially connected with liking. Brito et al. (2015) reported related results on gluten-free quinoa-based cookies, where panellists stated that they "maybe would buy" the cookies when questioned about their willingness to purchase the sample product. Fasolin et al. (2007) observed more scores ("neither like, neither dislike") on biscuit completed with banana flour in substitution of wheat flour. The Spearman rank correlation coefficient is the same as Pearson's correlation coefficient, however, it functions more on the data ranks rather than raw data. There are benefits of using Spearman's rank correlation coefficient than other common product instant correlation coefficient (Gauthier, 2001). The results from present research indicated that it is possible to modulate consumer acceptability and willingness-to-buy, of gluten-sugar-free banana flour based biscuits, by varying the concentration of shortening, milk and xylitol, added to the formulation. The analysis was able to separate sensory attribute with ingredients.

Table 20: Spearman's Correlation matrix of gluten sugar- free biscuit parameters at 5%, 10%, 15% and 20% with 55%, 50%, 45 and 40% % w/w levels of flour

Variables	**Milk Level**	**Xylitol Level**	**Shortening Level**	**Colour**	**Taste**	**Texture**	**Overall Acceptability**	**Willingness to buy**
Milk Level	1.00	-0.28	-0.26	0.02	-0.14	-0.12	-.011	-.012
Xylitol Level	-0.28	1.00	-0.25	-0.00	0.25	0.22	0.23	0.15
Shortening Level	-0.26	-0.25	1.00	0.14	0.07	0.07	0.08	0.10
Colour	0.02	-0.00	0.14	1.00	0.45	0.43	0.46	0.24
Taste	-0.14	0.25	0.07	0.45	1.00	0.93	0.95	0.60
Texture	-0.12	0.22	0.07	0.43	0.93	1.00	0.95	0.60
Overall Acceptability	-0.11	0.23	0.08	0.46	0.95	0.95	1.00	0.61
Willingness to buy	-0.12	0.15	0.10	0.24	0.60	0.60	0.61	1.00

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The influence of ingredient percentage on the physical and chemical features of green banana flour composite for making of gluten-sugar-free banana flour-based biscuits was investigated in this study. Composite green banana flour proximate analysis results showed a low moisture content resulted in a flour long shelf life. The results was in line with the recommended moisture content of commercial flour. Protein content of composite banana flour was lower than the recommended parameter for the bread flour, however low protein content flour does perform well in biscuit production. According to the findings of this study, milk, shortening, and xylitol have a vital effect in biscuit production as well as final biscuit features such as dimension, browning index, texture, and sensory assessment.

It was observed that the increase of ingredient (milk, shortening and xylitol) percentage of 5%, 10% and 15% increases the spread ratio of all biscuit samples. However, at 20% all biscuit samples presented a reduction in spread ratio. The overall browning index of biscuits baked varying ingredient percentage significantly increased ($P<0,05$) with increasing ingredient percentage. However, no substantial alteration detected in browning index of biscuit sample baked varying milk percentage of 15% (99.55) and 20% (102.6). Additionally, there was a substantial alteration in browning index of biscuit sample baked varying shortening and xylitol percentage.

For this work, ingredient variation during the dough sample preparation and baking process affected the texture of the final biscuit sample. The dough sample's handling properties, particularly throughout the sheeting process, revealed visible significant ($P<0, 05$) differences. Dough sample with 5% (82.21) milk, 5% (50.37) xylitol, and 5% (119.878) shortening was very firm. During the sheeting process, part of the dough sample broke off and the dough sample circle was very brittle. At 10% (25.59), 15% (13.27) xylitol, 10% (24.73), 15% (15.45) milk, and 10% (32.945), 15% (13.638) shortening dough sample became soft and easy to make a sheet, whereas at 20% (6.37) shortening, 20% (7.35) milk and 20% (10.88) xylitol dough sample became too soft and difficult to make a sheet. From all ingredients variation, shortening trend at a lower mean value of firmness and modulus which means biscuit sample baked with different shortening percentage resulted in soft chewable biscuit sample compared to biscuit sample prepared varying xylitol and milk percentage. The results statistically showed that all ingredient percentages formulations have a potential for the development of gluten and sugar free biscuit. At 55% flour and 5% (864.72) xylitol, 5% (617.8) milk and 5% (403.46) shortening, resulted in firm biscuit sample whereas at 50%, 45% flour and 10% (358.73), 15% (258.05) xylitol, 10% (315.73), 15% (266.48) milk, and 10% (283.90), 15% (248.41) shortening performed well for soft biscuit. The increase of the ingredients and decrease of flour percentage resulted on soft dough and chewable biscuit. The correlation results showed a strong relationship between taste, texture, overall acceptability and willing-to-buy. From the present results green banana flour composite and xylitol presented potential in the concocting of gluten-sugar-free biscuit for celiac sickness and diabetic patients. The present research indicated that it is possible to modify textural characteristics, of gluten-sugar-free banana flour based biscuits, by varying the percentage of xylitol, shortening, flour and milk added to the formulation.

5.2 Recommendations

From the results of the present work, green banana flour composite presented the capabilities to be applied as the main bakery constituent mainly for the production of biscuit. The use of xylitol to substitute sucrose as a sweetener and the use of gluten-free flour will benefit people suffering from diabetes and celiac disease to enjoy gluten and sugar-free biscuit. Gluten-free labelled products are knowingly high in price compared to gluten-containing products in the market, however, industrial process of green banana flour is less expensive. The resultant gluten-sugar free banana flour based biscuits would contribute to the alleviation of gluten intolerance and diabetes hence reduce the overall public and personal health bills associated with these non-communicable diseases. Optimization research are required to determine the optimum concentrations of the ingredients.

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Appendix

Consumer Sensory Evaluation Questionare use for the study

Welcome to biscuit sensory evaluation. The samples presented consist of safe ingredients and have been prepared in a way that is commonly used for preparing cookies and biscuits. The presenters of the samples will provide you with all the necessary information before giving you the samples for testing. Please ask for any information that you need to ask before you carry out the test.

Consent/Indemnity

I do agree that I have been well informed about the samples and accept to do the test on your own will. (Please tick?)

Yes:………………………. No:………………

Preliminary Information

Please provide the following information. Please circle

Gender: Male / Female

Age range: ≥20 20-30 30-40 40-50 50-60 ≥60

How often you buy biscuits or cookies. (Please tick✓). Every-day (__): Once a week (__): Once a month (__): Rarely buy (__): Never (__)

Cell phone number #:___________________ (only for follow up and quality control)

Instructions

You have been given 4 coded samples to taste. Please taste the samples from left to right. Before and in between the tasting, please eat a carrot provided.

Please indicate how much do **you like or dislike** the sample in terms of the **provided properties**. Please use the **rating faces** to indicate how much you like or dislike the samples. Please **tick (√)** your level of **like/dislike in the box on the row of the properties**.

Sample Code:………………

Rating Scale (1-9)	1-Dislike Extremely	2-Dislike Very Much	3-Dislike moderately	4-Dislike Slightly	5-Neither like/Dislike	6-Like Slight	7-Like Moderately	8-Like Very Much	9- Like Extremely
Colour									
Taste									
Mouth feel (Texture)									
Overall liking									
Would you buy this Sample? (Please Tick) Yes: No:									

Sample Code:………………

Rating Scale (1-9)	1-Dislike Extremely	2-Dislike Very Much	3-Dislike moderately	4-Dislike Slightly	5-Neither like/Dislike	6-Like Slight	7-Like Moderately	8-Like Very Much	9- Like Extremely
Colour									
Taste									
Mouth feel (Texture)									
Overall liking									
Would you buy this Sample? (Please Tick) Yes: No:									

Sample Code:………………

Rating Scale (1-9)	1-Dislike Extremely	2-Dislike Very Much	3-Dislike moderately	4-Dislike Slightly	5-Neither like/Dislike	6-Like Slight	7-Like Moderately	8-Like Very Much	9- Like Extremely
Colour									
Taste									
Mouth feel (Texture)									
Overall liking									
Would you buy this Sample? (Please Tick) Yes: No:									

Sample Code:………………

Rating Scale (1-9)	1-Dislike Extremely	2-Dislike Very Much	3-Dislike moderately	4-Dislike Slightly	5-Neither like/Dislike	6-Like Slight	7-Like Moderately	8-Like Very Much	9- Like Extremely
Colour									
Taste									
Mouth feel (Texture)									
Overall liking									
Would you buy this Sample? (Please Tick) Yes: No:									

Thank you very much for your participation