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DEPARTMENT OF FOOD SCIENCE AND TECHNOLOGY

SHELF STABILITY OF VACUUM PACKAGED PEELED PLANTAIN

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JUNE 2018

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A thesis submitted to the Department of Food Science and Technology,
Kwame Nkrumah University of Science and Technology, Kumasi
in partial fulfilment of the requirements for the award of

MSc. FOOD QUALITY MANAGEMENT

JUNE, 2017

DECLARATION/ CERTIFICATION

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma at Kwame Nkrumah University of Science and Technology, Kumasi or any other educational institution, except where due acknowledgment has been made in the thesis.

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ACKNOWLEDGEMENTS

My most special gratitude goes to the Almighty God, the Father in Heaven for granting me strength, knowledge, wisdom and divine directions throughout this project. My profound gratitude also goes to my supervisor Dr. Gloria Ankar-Brewoo and Dr. Isaac Williams Ofofu for their mentorship, technical guidance and support. To Redeemer Agbolebe, of the Food Science Laboratories-KNUST and all the TAs of the Food Science and Technology Department. I appreciate all their support and assistance, I say a big thank you and may God bless you.

My gratitude also goes to my husband, Isaac Kwesi Appiah, my children, Joe and Nana Adoma for their love and encouragement during my study and friends who supported me in diverse ways to make this study journey successful.

ABSTRACT

Plantain (*Musa spp*) is a tropical staple fruit in West Africa which belongs to the genus *Musa* of the family *Musaceae* is widely consumed in its green unripe state in Ghana. There is however limited available preservation techniques to maintain its green starchy stage after harvest. The objective of this study was to explore suitability of vacuum packaging in the preservation of green unripe plantain fruits. Unripe green plantain fruits were peeled, washed, sliced and blanched at different times. Blanched peeled plantain samples were vacuum packaged in different concentrations of saline solutions in high density polyethylene (HDPE) bags and stored for 30 days. The total sugar content of the stored samples were determined before storage and after storage using the Anthrone method. Data obtained were analysed using the Response Surface Methodology and ANOVA at 5% significance level. ANOVA results indicated the model, plantain variety, interaction of blanching time and NaCl treatment had significant effect ($p < 0.05$) on the sugar response. *Apantu* plantain variety blanched for 1 min and pretreated in 0.5% NaCl solution had the least total sugar response (10.44 %) whereas the least sugar response (18.17%) for *Apem* plantain variety was recorded for samples blanched for 5 min and pretreated in 0.3% NaCl solution.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Plantain (*Musa spp*) is a tropical staple fruit in West Africa (Akinsanmi *et al.*, 2015) and belongs to the genus *Musa* of the family *musaceae*. It is often in the form of a green crescent at harvest that changes to yellow upon ripening. The French horn (*Apem*) and giant horn (*apantu*) cultivars are the most commonly grown plantain in Ghana (Zakpaa *et al.*, 2010).

Plantain is high in dietary fibre, which is relevant in lowering cholesterol preventing constipation and also helps lower blood pressure (Ng and Fong, 2000). It also contains substantial amounts of potassium, magnesium and phosphate but low in fat (Adewale *et al.*, 2013). Because of its richness in potassium, it is highly recommended for individuals in need of diuretics (Best *et al.*, 1984; Alvarez-Acosta *et al.*, 2009).

Plantain as compared to banana contains more starch that is slowly broken down in the body when consumed (Soares *et al.*, 2011). This attribute (especially with unripen plantain) is highly appreciated amongst diabetics since it aids in the control of blood sugar concentration (Best *et al.*, 1984; Alvarez-Acosta *et al.*, 2009). Nutritionally, plantain has the tendency to provide a higher energy yield compared to most locally consumed foods. For every 100 g of the raw plantain fruit, about 112 kcal is obtainable, boiled fruit yields 122 kcal and the ripe fried fruit yields 267 kCal (Chandler, 1995).

Plantain has been used as a dietary source and cash crop in many countries found in Africa, Latin America and Asia (Akubor and Adejo, 2000; Mosha *et al.*, 2000; Dury

et al., 2002). Food and Agricultural Organisation (2010) reported Ghana to be the largest producer of plantain in West Africa with plantain being the third largest produced crop after yam and Cassava in the Ghanaian Agricultural sector contributing about 13.1 % to Ghana's Agricultural Gross Domestic Product.

According to Dzomeku *et al.* (2011), production of plantain has great socio-economic importance in Ghana. The Ghanaian agricultural industry is in the business of processing plantain into either flour or plantain chips. But locally, many Ghanaians are also into roasting and frying plantain into chips, 'kelewele', 'kaklo' and 'tatale'.

Plantain cultivation and harvest are faced with many challenges. Strong winds and rainfall highly affect harvest volumes and its availability during rainy and windy seasons (May-August) leading to high prices in dry seasons (September-March) (Dzomeku *et al.* 2011).

Once fruits are harvested, they are subjected to biochemical and microbial deterioration and as they continue to metabolize, losses in their edibility, quality and availability occur (Fallik and Aharoni, 2004). In addition, the plantain fruit is considered to be climacteric, ripening process occurs after harvest (usually between 2–7 days after harvesting) and does so rapidly once it commences (Kende, 1993; Robinson, 1996; Ogazi, 1996). Ripening is an irreversible process which changes the physiochemical properties of plantain (Prasanna *et al.*, 2007). Ripening of plantain fruit is hastened through mechanical injuries, temperature stress and chemicals present during transportation, storage and the immediate surroundings (Sharma and Singh, 2000; Brecht *et al.*, 2004). Thus plantain fruit is highly perishable and its deterioration overtime negatively affects its quality and quantity which may lead to higher selling prices.

Technologists have resorted to processing as a way of preserving the fruit (Thompson, 1995). Different methods for processing and preserving plantain fruits for storage to promote their availability in lean seasons have been developed. Including canning in syrups, application of extrusion, infrared and microwave technology to develop high valued end products (Thompson, 1995; Chandler, 1995). Dehydration via sun, oven, solar drying, convective drying and freeze drying have also been exploited (Johnson and Brennan, 2000; Falade *et al.*, 2003; Matazu and Haroun, 2004). Several drying methods have been found to significantly affect the physical, proximate, rheological and functional properties of plantain fruit (Pacheco-Delahaye *et al.*, 2008). Attempts aimed at canning plantain according to Sanchez-Nieva and Hernandez (1967) yielded poor results. Though freeze dried plantain gives better results it is considered expensive (Pacheco-Delahaye *et al.*, 2008). Drying via sun, solar and oven methods have been seen to have decreased the nutritional content (lipids, protein and carbohydrates) in some plantain (Agoreyo *et al.*, 2011; Hassan *et al.*, 2007). This could be attributed to lipid oxidation and Maillard reactions.

1.2 Problem statement

Plantains are easily cultivated and is therefore a cheaper traditional and functional food compared to other functional foods (Ruel *et al.*, 2004). It however perishes easily due to factors such as respiration, ethylene production and sensitivity, transpiration, compositional changes (Irtwange, 2011). But a longer life span of plantain can be achieved under proper storage conditions (Falade *et al.*, 2003). Preservation methods for plantain fruits include the above described drying methods which are currently the most commonly used. Little has been done in vacuum packaging of fresh pretreated plantain. Vacuum packaged fresh plantain has the potential being available for use in the preparation of *ampesi* which is a popular delicacy among most Ghanaians.

Therefore, the main objective of this study was to produce a vacuum packaged peeled blanched unripe plantain fruits and study its shelf stability with respect to its starchiness.

1.3 Hypothesis

Vacuum packaging combined with blanching and treatment in NaCl solutions would reduce if not eliminate the ripening process of unripe plantain. Hence vacuum packaging coupled with pretreatment could be used to maintain the starchiness of unripe plantain. Plantain variety, different blanching time and concentration of NaCl solutions would have a significant effect on the ripening of vacuum packaged peeled unripe plantain.

1.4 Justification

The findings of this study could be useful in providing an alternative method of processing plantain as well as provide information on the storability of vacuum packaged peeled unripe plantain. Vacuum packaged peeled unripe plantain could be available for the preparation of foods such as ampesi (raw plantain type) and fufu. These foods require the use of starchy unripe plantain. Pretreatment coupled with blanching could be useful for the preservation of the starchiness of plantain.

1.5 Objectives

The main objective of this study was to produce a vacuum packaged peeled blanched unripe plantain fruits and study its shelf stability with respect to its starchiness.

The specific objectives of this work were;

- To determine the appropriate blanching conditions for vacuum packaged peeled unripe *apantu* and *apem* plantain varieties.

- To determine the effect of blanching time, varying NaCl solutions on the shelf storability of vacuum packaged peeled unripe *apantu* and *apem* plantain varieties.
- To measure the total reducing sugar content of vacuum packaged peeled unripe *apantu* and *apem* plantain varieties after 30 days of storage under refrigerated conditions and at room temperature (25°C).

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Plantain

Plantain (*Musa spp*) is a staple and major carbohydrate food of many people in Africa, Asia, Latin and South America, the Carribean and the Pacific (Tchango *et al*, 1999; Abiodun-Solanke and Falade, 2010). It belongs to the *Musa* and *Musaceae* genus and family respectively. Plantain is also referred to as cooking banana or starchy banana thus plantain is the name for bananas that are eatable only after cooking (Simmonds, 1966; Mensah, 2013).

Plantain is a climacteric perennial crop which is also perishable especially in the high temperature zones. It fruits all year round hence ensures better food security among its farmers. In the work of Simmonds (1966), he reported the word plantain originated from the Spanish word *platano*. Plantains bear slender, starchy and relatively longer fruits compared to bananas. Plantain fruits vary widely based on the weight (50g – 300g), size, shape and color (Eshetu and Tola, 2014). In the study of Akubor and Adejo (2000), the pulp contributes about 62 % to the total weight of the plantain fruit.

In some literature, there is an unclear classification of plantain. However, three classes of plantain are said to exist namely; the False Horn Plantain, True Horn Plantain and French Plantain (Hemeng *et al.*, 1996; Ahiekpor, 1996). The study of Robinson (1996) however revealed that all plantain cultivars are derived from the *Musa acuminata* and *Musa balbisiana* species. *Apem*, *apantu* and *asamienu* are the local names for the French plantain, false horn plantain and true horn plantains respectively among the Akans of Ghana (Mensah, 2013). The apem and apantu

cultivars are the most commonly cultivated plantains in Ghana according to Zakpaa *et al.* (2010).

2.1.1 False Horn Plantain

False Horn plantains have incomplete inflorescence at maturity, 3 – 6 hands, few hermaphroditic flowers after the last hand, few long fat fingers and fruiting cycles not above 12 months (Montcel, 1987; Robinson; 1996). Also Montcel (1987) reported the false horn plantains bears bunches which weigh between 5 and 15 kg.



Plate 1.1 False Horn Plantain

Source: <http://www.promusa.org/Plantain+subgroup>

2.1.2 True Horn Plantain

Like the false horn plantain, true horn plantains also have incomplete inflorescence at maturity. However, they usually have between 1 – 3 hands per bunch with relatively lesser (lesser than 10) and larger fingers (Montcel, 1987; Komatsu *et al.*, 2010). This implies the true horn plantain has a relatively lower yield and therefore, a larger land area and energy may be required to achieve a given higher yield.



Plate 1.2. True Horn Plantain

Source: <http://www.promusa.org/Plantain+subgroup>

2.1.3 French Plantain

French Plantains are characterized by comparatively long fruiting cycles (15 – 18 months), relatively smaller yet greater number of fingers, a complete inflorescence at maturity and more than 10 hands per bunch (Montcel, 1987; Komatsu *et al.*, 2010; Mensah, 2013). Nine (9) varieties of French plantains are known and are cultivated across India, Central America and Africa including Ghana (Robinson, 1996).



Plate 1.3: French Plantain

Source: <http://www.promusa.org/Plantain+subgroup>

2.1.4 Differences between Plantain and Banana

Although plantain is said to belong to the bananas, it differs from other bananas based on its eatability, size, length, peel density and starchiness. According to Gourmet Plantain Chips (2009), plantains have denser peels, are less sugary, have longer and bigger fingers and are only eaten after cooking. The less sugary nature of plantains makes them starchier than the other bananas. Plantains are eaten in Ghana only after cooking either by roasting, boiling or frying whereas the eatable bananas are usually eaten as fresh fruits. Bananas become eatable once they are well ripened where they are either simply peeled by the hand and eaten, sliced and eaten in fruit salads as well as blended and made into fruit smoothies (Adeniji *et al.*, 2006). It is also reported plantains de-green faster than bananas during ripening under the same conditions of storage (Kajuna *et al.*, 1998).

2.2 Plantain Production and Supply in Ghana

In Ghana, plantain is cultivated mostly in the forest zones of the country, fruits throughout the year and usually after between 12 – 18 months of planting depending on the specific variety. Like in many other producing countries, in Ghana, plantain is usually cultivated in the backyard garden, mixed cropping system and or in the monoculture system (INIBAP, 1992). Tchango *et al.* (1999) stated plantain is cultivated in the mixed cropping system with coffee in Venezuela, Costa Rica and Colombia. In Ghana and other producing African countries plantain is commonly cultivated in the mixed cropping system with cassava, yam and cocoyam.

The mean annual production of plantain increased from 2279 000 MT in 2002 to 3556 000 MT in 2012 (MoFA, 2012) as shown in Table 2.0. Reports compiled by Dankyi *et al.* (2007) from MoFA and SRID revealed that the estimated annual production of plantain increased with increased alongside its estimated total area of cultivation, its

annual per capita consumption and population growth. This indicates plantain has a great role in ensuring food and nutrient security for the increasing population. Hence the need to investigate more suitable methods of preservation for plantain to support the existing methods and to further reduce its wastage.

Table.2.0 Estimated Annual Plantain Production, Total Area Planted to Plantain and Annual per Capita Consumption of Plantain in Ghana

Year	Annual production (‘000 MT)	Per Capita Consumption (kg/annum)	Total Area Planted (‘000 ha)
2001	-	-	265
2002	2279	-	277
2003	2329	-	286
2004	2381	-	281
2005	2792	40	290
2006	2900	-	299
2007	3234	-	305
2008	3338	-	312
2009	3563	-	325
2010	3538	38	328
2011	3619	-	336
2012	3556	-	337

Source: MoFA (2012)

Agness (2009) reported that plantain cultivation in Africa over the last 30 years has almost doubled to 27 million MT. Ghana together with Uganda, Rwanda, Nigeria and Cameroon is one of the top producing countries of plantain in sub-Saharan Africa as reported by IITA (2009). Meanwhile, a study conducted by FAO (2010) revealed Ghana is the largest producer of plantain in West Africa.

The larger production of plantain is attributed to its ease of cultivation. According to FAO (2004), plantain cultivation requires relatively little effort in land preparation,

fewer cultural practices usually weed control and staking. Plantain cultivation in Ghana usually does not require fertilizer application.

2.2.1 Harvesting, Packaging and Transport of Plantain Fruits

Harvesting of plantain in most producing areas is mostly carried out manually with a cutlass or machete as the harvesting tool. For the dwarf variety of plantain, the bunch is cut directly from the plant without cutting down the whole plant. However, plantain varieties with relatively taller pseudostems are harvested by cutting through the pseudostem to make the plant bend slightly, in order to bring the bunch to a reach where it can then be cut off (Tchango *et al.* 1999). This method of harvesting subjects the plantain fruits to mechanical injuries since there is high possibility of the bunch falling on the ground in the process (Wainwright and Burdon, 1991; Dadzie, 1994) which may lead to poor quality plantain fruits.

Plantain fruits after harvest are either deheaded or transported while on the bunch. In Ghana, harvested are transported home or to the market by carrying in baskets (mostly by women), on the shoulders (usually men) as well as at the back of bicycles and motorbikes. However, larger quantities of plantain are transported in trucks where the bunches or deheaded fingers are usually stuck on one another. These transportation methods are known to expose plantain fruits to mechanical damage (Marchal, 1990; Wainwright and Burdon, 1991; Dadzie, 1994; N'da Adopo *et al.*, 1996) which eventually leads to increased postharvest losses

Plantain fruits are usually sold unpackaged in most Ghanaian markets. At the retail markets, they are usually deheaded from the bunch, grouped into smaller portions on either a table or on polyethylene material spread on the floor and sold to consumers.

This mode of sale exposes the fruit to higher temperature, microbial contamination, mechanical injuries which occur during handling and subsequently to quality losses.

On the other hand, plantain fruits for the export market are usually deheaded and packaged in perforated reusable plastic containers (Tchango *et al.*, 1999). This mode of packaging allows plantain fruits to be transported under aerated conditions, conditions which minimize mechanical damage and reduces quality losses. Non-cooking banana fruits which are closely related to plantain fruits have been successfully packaged in polymeric films for the retail and export markets. Due to their waterproof nature, polymeric film packages maintain a humid environment around the fruit and therefore reduces dehydration and prevents weight loss (Anyindana, 2016).

2.2.2 Ripening Process of Plantain Fruits

Plantain fruits are usually harvested at the unripe green and firm stage (Siriboon and Banlusilp, 2004). As a climacteric fruit, plantain fruits undergo three physiological stages including; the pre-climacteric stage, ripening stage and senescence which eventually leads to death (Kende, 1993; Robinson, 1996; Ogazi, 1996). According to Prasanna *et al.* (2007), ripening is an irreversible process which changes the physicochemical properties of plantain. It is said to be induced by the production of ethylene gas via biochemical processes within the fruit or by the introduction of ethylene gas from an external source.

Ethylene gas (C₂H₄) is biosynthesized from methionine within the tissues of the fruit and as a hormone stimulates the starch hydrolysis, tissue softening and chlorophyll degradation of ripening fruits. Ethylene stimulates the production of amylase enzymes which is responsible for the starch breakdown to sugars leading to sweetness

and pectinase which catalyzes the breakdown of pectin in the cells resulting in tissue softening and reduced firmness of ripened fruits (Koning, 1994; Fajinmi *et al.*, 2011).

According to Seymour (1993), ripening increases the sweetness of plantain fruits, decreases the firmness and increases the moisture of plantain fruits. Mechanical injury, high temperatures, oxygen, chemicals within the postharvest environment promote the ripening process of plantain fruits (Sharma and Singh, 2000; Brecht *et al.*, 2004). Traditionally, plantain is ripened for consumption by storing fruits in dark airtight or enclosed places usually in jute or polyethylene bags, earthen pot and at times with high ethylene producing fruits such as apple and arvingia (Fajinmi *et al.*, 2011). Storage in airtight or enclosed areas ensures the retention of the produced ethylene gas around the fruits which facilitates the ripening process (Anyindana, 2016). Therefore, preservation methods aimed at maintaining the fresh, green and starchy quality of plantain fruits ensure the elimination of factors that promote ethylene production and/or retains ethylene in the storage environment.

2.3 Uses of Plantain Fruits

Plantain provides daily food for about 70 million people in West Africa (Eshetu and Tola, 2014). It has many uses in traditional dishes which is either fried or boiled, roasted or pounded and eaten with other food complements or sometimes processed into beverages (Akubor, 2003; Mohapatra *et al.*, 2009). It can be consumed unripe (green), slightly ripened (yellowish-green) or fully ripened (yellow) once it has been boiled, fried or roasted (Baiyeri *et al.*, 2011). Plantain fruits are also used in feeding livestock.

2.3.1 Unripe Plantain Fruit

Unripe plantain is usually boiled and pounded to make fufu (Ogazi, 1996), which is usually eaten with soup (palm nut, groundnut or light soup). In Ghana, it is commonly sliced and fried into chips and is eaten as a snack. It is often boiled and eaten with stews (palava sauce and garden egg stew) commonly referred to as ‘ampesi’ in the traditional settings. A popular dish amongst the Akans in Ghana known as ‘abom’ also makes use of boiled unripe plantain.

2.3.2 Ripe Plantain Fruit

Ripened plantain is sometimes eaten raw (Baiyeri *et al.*, 2011). They are also often fried and eaten with boiled beans (‘red red’) and rice or sometimes alone. Boiled ripe plantain is also eaten with stew or ‘abom’ (a local accompaniment prepared from vegetables) among the Akans of Ghana. Again, in Ghana ripen plantains are sometimes cut into cubes, seasoned with spices and fried into ‘kelewele and complemented with roasted groundnut. Over ripened plantain is also often mashed with pepper and ginger, mixed with flour and deep fried to make ‘kaklo’ or ‘tatale’. In some African countries, alcoholic and non-alcoholic beverages are made out of ripe plantain. It is used in making a beer called ‘agadangidi’ Nigeria (Adewole, and Duruji, 2010).

2.3.3 Processed Plantain

Plantain can be processed into different food products during different stages of ripening (Falade and Abiodun-Solanke 2010). Unripe plantains are often processed into flour and incorporated into foods to enhance their functional properties (Thompson, 1995; Abulude and Ojediran 2006). In Nigeria, unripe plantain flour is used to prepare a thick paste meal known as ‘amala’ (Adeniji *et al.*, 2006). Ripened plantains are also sliced and canned in syrup which are later boiled and consumed

(Abiodun-Solanke and Falade, 2010). Plantain flour has been successfully used in the production of baby food in Nigeria (Ogazi, 1996). Also, Morelle (1997) reported plantain flour fritters and cakes were well accepted by Cameroonian consumers. According to Mohapatra *et al.* (2009), plantain flour is used in making functional foods since they confer some properties.

2.3.4 Non-food Uses

Plantain has been reported to have some medicinal properties (Abiodun-Solanke and Falade, 2010). Gill (1992) reported the fruit can be used as an antiscorbutic, aphrodisiac and a diuretic. It is used in treating diseases such as ulcer and wounds particularly due to its anti-ulcerogenic, antimicrobial, anti urolithiatic and analgesic properties (Kumar *et al.*, 2012).

2.4 Nutritional Value of Plantain

Izonfuo and Omuaru (1988) who investigated the effect of ripening on the chemical composition of plantain peels and pulp reported the plantain peels to contain higher concentrations minerals than the pulp. The bioavailability of these minerals may however be limited by the high levels (112.6 – 241.4 mg/100g) of tannins in the peels reported by Ogazi (1996).

The raw plantain pulp was reported to contain 122 Cal/100g energy, 0.37 % total fat, 0.14 % saturated fat, 31.9 % total carbohydrates, 2.3 % fibre, 15 % sugars and 1.3 % protein (Tythan, 2011). Whereas Oko *et al.* (2015) reported a generally higher proximate values for 8 plantain varieties. In their study, unripe plantain was found to contain 10 – 18.30 % moisture, 0.55 – 2.53 % ash, 0.19 – 0.61 % fibre, 2.05 – 4.07 % fat, 1.12 – 7.24 % protein, 69.69 – 81.18 % available carbohydrates, 264.75

- 381.25 mg/kg potassium, 102.15 – 162.04 % calcium and 152.69 – 260.21 % phosphorus.

Plantain is also said to be low in sodium, cholesterol (Chandler, 1995) and also a low glycemic index food with GI ranging between 39.04 – 51.05 % (Oko *et al.*, 2015). Plantain is therefore recommendable as a healthy food product to diabetics and individuals with hypertension.

Table 2.1 The Nutritional Value per 100g of Plantain as Reported by USDA (2011)

Nutrient	Amount
Energy (kCal)	120
Carbohydrate (g)	31.9
Dietary Fibre (g)	2.3
Protein (g)	1.3
Fat (g)	0.37
Vitamin A equivalent (µg)	56
Thiamin (mg)	0.052
Riboflavin (mg)	0.054
Niacin (mg)	0.686
Vitamin B6 (mg)	0.3
Folate (µg)	22
Vitamin C (mg)	18.4
Vitamin K (µg)	0.7
Calcium (mg)	3
Iron (mg)	0.6
Magnesium (mg)	37
Phosphorus (mg)	34
Potassium (mg)	499
Zinc (mg)	0.14

Mepba *et al.* (2007) who studied the chemical composition and baking properties of plantain-wheat composite flours reported plantain flour contains 2.30 % protein, 1.64 % lipids, 3.50 % crude fibre, 2.36 % ash and 78.72 % carbohydrates. These values are contrary to the findings of Tythan (2011) stated above and USDA (2011) as shown in Table 2.1 above.

2.5 Quality Attributes of Plantain

The quality attributes of plantain may either be physical attributes such as color, length, size, shape and texture or chemical attributes such as total sugar (total soluble solids or Brix), pH and titratable acidity. The quality parameters of plantain are selected based on its target end use.

Unripe plantain is high in starch. The starchy nature of unripe plantain is suitable for *fufu* – a highly viscous paste consumed in Ghana and some other parts of Africa. Ripe plantain on the other hand is low in starch due to elevated hydrolytic enzyme activity during the ripening (Abiodun-Solanke and Falade, 2010). Ripe plantain therefore may be considered as a poor quality plantain as a raw material for *fufu*.

The absence of disease conditions and mechanical damages are also indicators for good determining quality plantain fruits. Fungal diseases such as anthracnose, cigar-end rot disease and cercospora disease reduce the quality of plantain fruits and therefore their suitability for consumption (Momambo, 1993; Jeger *et al.*, 1995; Tchango *et al.*, 1999). For example the cercospora disease reduce the quality of plantain fingers via the reduction in the pulp content by about 30 % as reported by Momambo (1993).

Cigar-end rot and anthracnose causes rotting of the plantain fruits during ripening which eventually leads to a shorter postharvest life and increased losses of the fruits

during storage (Jeger *et al.*, 1995). The presence and the degree of mechanical damage of the plantain fruit may also initiate or promote the rotting process.

2.5.1 Maturity and Size

A varying number of internal and external factors are considered in determining the maturity of plantain. Johnson *et al.* (1998) identified fruit diameter, length, bunch age and color as some of the external factors for determining the maturity of plantain. According to Ogazi (1996), the Vernier calipers is the tool for measuring the diameter of plantain fruits. Farmers usually harvest plantains to be transported to farther destinations in their greenish state as a way of reducing the losses due to rotting during the period of transportation.

Other maturity determining factors include peel to pulp ratio, fruit firmness, shape, presence or absence of distinct ridges on the fruit, diameter and fruit length (Thompson and Burden, 1993). Immature plantain fruits have more distinct ridges and are less rounded in shape. Abiodun-Solanke and Falade (2010), plantain fruits to be frozen after harvest are physiologically matured at a pulp to peel ratio of 1.5.

Maturity factors could be influenced by environmental factors such as rainfall and soil characteristics such as soil type, soil moisture and soil nutrient (Dzomeku *et al.*, 2016) hence may be unreliable. For example, the presence of distinct ridges on the fruit could be deceptive in the dry season.

2.5.2 Color and Texture

The quality of plantain with respect to color and texture is dependent on its target end-use. The color of plantain at physiological maturity green (Ogazi, 1996; Johnson *et al.*, 1998) but changes to yellow at the ripe stage and dark brown at the overripe stage or death stage. The yellow color of ripened plantain is due to the presence of

carotenoids including xanthophyll in the chromoplasts (Blackbourn *et al.*, 1990) which are revealed as chlorophyll degrades upon ripening.

However, it has been reported that chlorophyll degradation during ripening was decreased at higher temperature of storage. This was revealed in the study of Thomas and Janave (1992) when they found that Cavendish bananas stored at 30 – 34 °C retained up to 98% of chlorophyll whereas storage at 20 °C retained only 60 % chlorophyll.

The texture of plantain at the green unripe stage is usually hard with much firmness. Firmness decreases with ripening of the plantain fruit (Plainsirichai *et al.*, 2003; Anyindana, 2016). The decrease in firmness of fruits during ripening is attributable to tissue softening which results from pectinase activity which catalyzes the breakdown of pectin in the cell walls (Koning, 1994; Fajinmi *et al.*, 2011). Plantain fruits with soft texture are less starchy and unsuitable for *fufu* which requires starchy fruits to acquire its characteristic viscosity. They are however suitable for foods such as ‘*tatale*’, ‘*kaklo*’ (Abiodun-Solanke and Falade, 2010) and ‘*kelewele*’.

2.5.3 Pulp to Peel Ratio of Plantain

The pulp to peel ratio of plantain varies across the various species and varieties. It is an indicator for plantain quality which provides information on the economic importance of a particular plantain variety. Plantain fruits with higher pulp to peel ratios are more suitable for productions aimed at ensuring food security (Eshetu and Tola, 2014). Available literature indicates the average pulp to peel ratio of many plantain varieties is 1:1 (Ogazi, 1990; Akubor and Adejo, 2000; Eshetu and Tola, 2014). The pulp to peel ratio of plantain may also indicate its maturity (Abiodun-

Solanke and Falade, 2010) since the pulp content of the plantain fruit increases with maturity.

2.5.4 Total Sugar, pH, Titratable Acidity

‘The conversion of starch to sugars is the most important change in ripening bananas’ according to Anyindana (2016). Ethylene gas produced by ripening fruits activates amylase which catalyzes the hydrolysis of starch to sugars (Seymour, 1993; Koning, 1994; Fajinmi *et al.*, 2011; Hailu *et al.*, 2012). The resulting sugars contribute to the sweetness and the total soluble solids content of ripened fruit. Hence total soluble solids increases with storage time (Yang *et al.*, 2009; Hailu *et al.*, 2012).

Titrate acidity increases with decreasing pH during ripening (Gowen, 1995; Hailu *et al.*, 2012; Zomo *et al.*, 2014; Anyindana, 2016) and reaches its peak at full ripeness (Anyindana, 2016). The vice versa was reported by Anyindana (2016) to occur during the senescence stage. This was attributed to the fact that, more organic acids are released from the tissues during ripening than at senescence to aid in the chlorophyll degradation and fruit yellowing processes.

2.6 Shelf Life and Postharvest Losses of Plantain

Plantain is a climacteric fruit and therefore undergoes metabolic processes including respiration and transpiration even after harvest. As a catabolic process, respiration coupled with ripening processes eventually leads increased enzymatic breakdown of available starches to simple sugars, degradation of chlorophyll and tissue softening as a result of increased pectinase activity (Marriot and Lancaster, 1983; Ogazi, 1996; Abiodun-Solanke and Falade, 2010). Under poor storage conditions and handling methods, these processes lead to decreased quality during postharvest management.

Unfavorable storage conditions allows rapid ripening and subsequent spoilage of harvested plantains (Daniells *et al.*, 2001). This is reported to occur most at the producer level along the supply chain according to N'da Adopo (1993). Tchango *et al.* (1999) revealed that at 302 °C and 202 °C plantain harvested at the matured green stage could be stored in plastic bags filled with powdered cocoa leaves and rice for 14 – 20 days and 24 – 27 days respectively.

2.7 Processing and Preservation of Plantain

Fresh plantain fruits contain about 10 – 18.18 % moisture (Oko *et al.*, 2015). This amount of moisture may promote the growth of spoilage microorganisms and eventually lead to losses during storage. Methods such as drying are employed by plantain processors to reduce the inherent moisture content to level unfavorable for microbial growth. According to Egbebi and Bademosi (2011), air and sun drying methods are the most commonly used drying methods for drying plantain. Drying methods such as oven, solar and freeze drying methods have also been used to preserve plantain (Johnson and Brennan, 2000; Falade *et al.*, 2003; Matazu and Haroun, 2004). Other methods which have been successfully used in processing plantain fruits include; extrusion, infrared drying and microwave technology (Thompson, 1995; Chandler, 1995). However, these methods could only preserve plantain for further processing into flours and powders or packaged as dried plantain chips.

Besides air and sun drying methods, oven-drying and foam-mat drying have also been successfully used in drying plantain to produce flour (Johnson *et al.*, 1998; Demirel and Turhan, 2003; Falade and Olugbuyi, 2009). For plantain powder production, spray and drum drying methods were successfully used according to Thompson (1995).

Plantain after drying is further processed into flours and powders for use as wheat flour substitutes in baked products such as bread, biscuits and cake (Ngalani and Crouzet, 1995; Mepba *et al.*, 2007). Ripe plantain is also preserved by processing into jams, jellies (Chandler, 1995; Abiodun-Solanke, 2010) whereas unripe, partially ripe and fully ripe plantain fruits are also processed into chips.

Plantains are usually hand peeled, sliced into smaller sizes and air dried. Endogenous browning enzymes such as peroxidases, oxidases and catalases promote the formation of dark or brown pigments on the surfaces of the dried material via enzymatic browning reactions during the process (Ngalani, 1989; Tchango *et al.*, 1999). Pretreatments such as blanching, treatment with citric acid or sodium metabisulphite solutions have been used to retain the original yellowish color of plantain after drying and also to obtain aesthetically appealing plantain flour (Ngalani, 1989). It is revealed that little has been done to preserve sufficiently starchy plantain fruits for future usage in the preparation of '*ampesi*'.

Preservation of fresh green mature plantain fruits involve methods to prevent dehydration and ripening of the fruit. According to Tchango *et al.* (1993), this is achieved traditionally by piling bunches of harvested plantains under shades or covering with plantain leaves and bags. Dehydration is prevented by regular moistening with lower temperature water. Agbo *et al.* (1996) reported green mature plantain was successfully preserved in Cote D'Ivoire by wrapping bunches of plantain with plastic bags filled with powdered cocoa leaves or rice husk. This method was aimed at reducing air circulation around the fruits and slowing the ripening process.

Lower temperature storage also reduces the enzymatic activities during the ripening process. Therefore storage at temperatures between 12 °C to 14 °C was reported to be

suitable for extending and maintaining the shelf life of fresh green plantain (Marchal, 1990; Collin, 1991) especially when coupled with packaging in plastic bags.

2.7.1 Effect of Preservation by Drying on Plantain Quality

Drying as a method of preserving plantain fruits is limited by the limitation of plantain utilization and also resulting discoloration of the dried products which may lead to the loss of aesthetic appeal and nutrients. Drying limits the use of plantain since dried plantain could not be used for ampesi which is a popular delicacy among the Ashanti, Eastern, Brong Ahafo and Central regions of Ghana. Pacheco-Delahaye *et al.* (2008) in their study on production and characterization of plantain flours reported that drying reduced the proximate, rheological, physicochemical and functional properties of plantain flour. Sun, solar and oven drying methods were also found to decrease the lipid, protein and carbohydrate contents plantain fruits and other plant materials (Hassan *et al.*, 2007; Agoreyo *et al.*, 2011). The losses of nutrients is attributed oxidation and both enzymatic and non-enzymatic reactions which occur during the process of drying (Di Scala, 2008). Although an expensive method, freeze drying was reported to significantly retain the nutritional value of the plantain fruit (Pacheco-Delahaye *et al.*, 2008).

2.8 Blanching

Blanching is a mild thermal pre-treatment for vegetables and a process aimed at deactivating undesirable enzymes and reduction of microbial activities to increase the shelf stability and life of food produce. As a pretreatment, blanching is usually used to prepare foods for further processing including drying, freezing and packaging (Fellows, 2000; Ayim *et al.*, 2012). Elimination of browning is the major reason for blanching foods prior to other processing methods.

It is a commonly used method for deactivating quality deteriorating enzymes in fruits and vegetables (Gamboa-Santos *et al.*, 2012). Target enzymes for blanching include; polyphenol oxidases (PPO), catalases, peroxidases which cause browning in fruits and vegetables processed for storage. Blanching however may deactivate other inherent enzymes such as amylases, pectinases, lipoxygenases and phenolases in food materials. The possibility of deactivating hydrolytic enzymes makes blanching applicable in the preservation of food materials whose quality depends on their starchiness.

The most commonly used blanching methods include hot water blanching and steam blanching. Although hot-water blanching has been employed to limit enzymatic and non-enzymatic browning in foods (Akanbi *et al.*, 2003; Kingsly *et al.*, 2007), it is also known to contribute more to nutrient losses compared to steam blanching.

Generally, blanching is reported to contribute to nutrient losses via leaching or thermal degradation in blanched food products in the studies of Taiwo *et al.* (2001), Sablani (2006), Taiwo and Adeyemi (2009) and Gamboa-Santos *et al.* (2012). In their works, it was revealed that blanched carrot, apple, ripe and unripe banana fruits had reduced contents of vitamin C, total mineral and total fat. Soria *et al.* (2008) also reported blanching contributed to flavor loss which resulted from loss of volatile compounds during the blanching process.

2.9 Vacuum Packaging

Vacuum packaging is a preservation that can be used to preserve foods including meat, fruits and vegetables in its various forms and stages of existence (Conie and Young, 2003). It involves the use of plastic films to create a sub-environment low in oxygen and/or high in CO₂ around the food material (Kader, 2000; Dick, 2006). This

could best be achieved using a vacuum packaging machine. Plastic films suitable for packaging should be resistant to punctures and impermeable to air.

Vacuum packaging technology has been successfully used in recent studies to slow down ripening and deterioration of banana and plantain during storage (Dongo *et al.*, 2011; Hailu *et al.*, 2012; Anyindana, 2016). Vacuum packaging, which excludes oxygen from the product package, prevents oxidation which may lead to discoloration, growth of aerobic bacteria which may promote spoilage, transpiration and also slows aerobic respiratory within the cells of the fruits.

As a result, vacuum packaging has advantages including prolonged product marketability after harvest as revealed by Hailu *et al.* (2012) who investigated the effect of packaging material on the quality of banana. The prevention of both enzymatic and non-enzymatic oxidation during storage is another benefit of vacuum packaging (Conie and Young, 2003) hence ability to prevent oxidative rancidity and browning in stored food materials.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

Fresh unripe plantain fruit varieties of False Horn (*Apentu*) and French (*Apem*) used were obtained from the Bantama market of Kumasi in the Ashanti Region.

3.1.1 Preparation of samples

The plantain fruits were washed, peeled, sliced into equal sizes of approximately 8 cm were packed with a total weight of between 100 and 120 grams. Each portion was blanched in 100°C autoclaved water for 1, 2, 3, 4 and 5 minutes using a kitchen saucepan and colander. The 100 mls Saline (NaCl) solutions of concentrations 0.1%, 0.2 %, 0.3%, 0.4 %, and 0.5% was added to the pre-weighed sample in the sealing bag and sealed .

3.2 Methods

3.2.1 Research design

A temperature time processing design was designed using Response Surface Methodology design from Stat – Ease Expert Design Statistical Software (Design Expert version 9.0.2.0, 201).

3.2.2 Vacuum Packaging and Storage

The blanched plantain samples were cooled to room temperature and vacuum packaged in the prepared saline solutions and sealed in high density polyethylene (HDPE), using the single vacuum chamber packaging machine (Jumbo 42, Model: HOJ30161547, Netherland) and samples from each blanching time were packaged in the various saline solutions according to the experimental runs generated using the design expert software (find model) in Appendix I. Packaged samples were stored

under refrigeration at 15°C and at ambient temperature of 27-28°C. The total reducing sugar content of the samples before storage and after 30 days of storage was determined.

3.3 Determination of Total Reducing Sugar

The total sugar content of the plantain samples were determined by using the Anthrone's Test. The Anthrone reagent was prepared by dissolving 2 g of anthrone in 100 mL concentrated sulfuric acid (H₂SO₄). A stock glucose solution of a concentration of 100 mg/mL was also prepared. A range of serial dilutions of glucose of 10 – 100 mg/mL in test tubes was set up. A blank sample was also set up with 1 mL distilled water only.

A standard curve was drawn using the absorbance values of the standard glucose. This was used to calculate the amount of the unknown glucose concentration in the samples.

A one ml of the test sample was transferred into a test tube. 4 ml of the Anthrone reagent was added to each test tube, mixed and incubated in a boiling water bath for 10min.

The test tubes were cooled to room temperature and the absorbance of the analyte measured at 620 nm using a spectrophotometer model after setting to zero absorbance using the blank.

3.4 Statistical Analysis

The response data obtained was loaded into the statistical tool (Design Expert, 2007) and run to generate regression parameters, ANOVA and other statistical parameters. Data collected were initially fitted to models that could explain the behaviour of the treatment factors and responses over the design space. This involved studying such

coefficients as the standard deviation, regression- (R^2), adjusted regression- (adj R^2), prediction regression-(pred R^2), adequate precision -(adeq precision) and (PRESS) of the models selected. The p-values for the regression models as well as the interactions among the factors of design were tested against $p < 0.05$. Statistical significance of the terms in the regression model was examined by analysis of variance (ANOVA) for each response. To evaluate the goodness-of- fit of the models, regression (R^2), F-value, the derived P values and coefficient of variance (CV) were evaluated. The lack-of-fit term was also used to judge adequacy of the model fit.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Fitting the data collected

Plots such as the model designs were obtained to explain the behavior of the sugar response against the blanching time, plantain variety and NaCl treatment. A summary of the analysis of variance statistics and the model fitted indicated the standard deviation, the R-Squared and adjusted R-Squared, predicted R-Squared and the predicted residual error sum of squares (PRESS). These were indicators of how well the chosen models fitted the data (Design Expert, 2007).

4.2 Total sugar content of the pretreated vacuum packaged peeled plantain

The predicted R-squared of 0.6589 is in reasonable agreement with the adjusted R-squared of 0.8223 suggesting the adequacy of the data. Adequate precision measures the signal to noise ratio and a ratio greater than 4 is desirable (Montgomery and Myers, 2002). The ratio of 11.906 obtained for the data in this study indicated an adequate signal hence the experimental model could be used to navigate the design space. This is as shown in Table 4.1.

Table 4.1 A summary of the analysis of variance statistics for the total sugar response for the vacuum packaged peeled plantain

	Std.	Mean	C. V. %	PRESS	R-	Adj. R-	Pred. R-	Adeq
	Dev.				Squared	Squared	Squared	precision
Total Sugars	8.96	49.36	18.14	2771.22	0.901	0.822	0.659	11.906

Source: Field data

From the ANOVA table as summarized in Table 4.2, the model had an F-value of 11.41 and a p-value of 0.0004 which implies the study model was significant. There is

only 0.04% chance that a model F-value this large could occur as a result of noise. Plantain variety, the interaction of blanching time and NaCl treatment as well as the interaction of NaCl treatment and plantain variety had a significant ($p < 0.05$) effect on the sugar response. Blanching time, NaCl treatment and interaction of blanching time and plantain variety had no significant effect on the total sugars of the peeled vacuum packaged plantain. These models had p-values greater than 0.10. The ANOVA also showed that the Lack of Fit was not significant relative to the pure error since the F-Value was 0.59. There was a 71.37 % chance that a lack of fit F-value this large could occur due to noise.

Table 4.2 A summary of the analysis of variance for the total sugar of the peeled vacuum packaged plantain

Factors	F Value	p-value
Model	11.41073	0.0004
A-Blanching Time	0.703544	0.4212
B-NaCl Treatment	0.417965	0.5325
C-Plantain Variety	18.00219	0.0017
AB	8.048975	0.0176
AC	2.883889	0.1203
BC	53.9653	< 0.0001

Source: Field data

Table 4.3 shows the total sugar response for vacuum packaged peeled plantain as influenced by variety, blanching time and NaCl treatment. The total sugar response for Apantu variety ranged from 10.44 % to 87.02 % after storage for 30 days.

Statistically, blanching time and NaCl had no significant effect on sugar response of vacuum packaged peeled plantain.

Table 4.3 Effect of blanching time, NaCl treatment and plantain variety on total sugar response of vacuum packaged peeled plantain

Run	Factor 1	Factor 2	Factor 3	Response
	A:Blanching Time (min)	B: NaCl Treatment (%)	C:Plantain Variety	Total Sugars (%)
1	5	0.5	Apantu	31.21
2	1	0.1	Apantu	45.82
3	3	0.1	Apantu	87.02
4	3	0.5	Apantu	41.39
5	5	0.1	Apantu	48.75
6	2	0.3	Apantu	33.30
7	1	0.5	Apantu	10.44
8	1	0.1	Apantu	76.69
9	3	0.5	Apantu	41.98
10	5	0.5	Apem	80.64
11	5	0.1	Apem	32.38
12	1	0.5	Apem	68.44
13	5	0.1	Apem	30.53
14	1	0.5	Apem	74.89
15	1	0.1	Apem	52.70
16	5	0.3	Apem	18.19
17	1	0.3	Apem	50.23
18	1	0.1	Apem	56.28
19	3	0.2	Apem	56.98

Source: Field data

However, the minimum total sugar response was observed for plantain samples blanched for 1 min and treated in 0.5% NaCl solution prior vacuum packaging and storage. Blanching deactivates hydrolytic enzymes (Gamboa-Santos *et al.*, 2012) and saline solution prevents microbial growth via a dehydration mechanism. These could

be responsible for the minimum sugar response observation at 1 min blanching and 0.5% NaCl treatment.

For the Apem variety, sugar response after the storage period ranged from 18.19 % - 80.64 %. The minimum sugar response (18.19 %) was observed for plantain samples blanched for 5 mins and treated in 0.3 % NaCl solution prior to vacuum packaging and storage. The differences in the minimum sugar response for the *Apantu* and *Apem* varieties of plantain in this study could be attributed the differences in their starch characteristics such as amylose-amylopectin ratio. Researchers have argued that amylopectin is easily hydrolyzed compared to amylose due to its branched structure (Brand-Miller *et al.*, 1992; Foster-Powell *et al.*, 2002). Since the sugar response of plantain corresponds to the level of starch hydrolysis, the relatively higher minimum sugar response in the Apem variety could signal a lower level of starch hydrolysis during storage.

For the Apantu variety and from Figure 4.1, the total sugar response was higher at blanching times between 2 and 4 mins coupled with sealing in NaCl solution with concentrations ranging from 0.10% to 0.12 % whilst reaching its highest at 3mins blanching followed by vacuum sealing in 0.10 % NaCl solution.

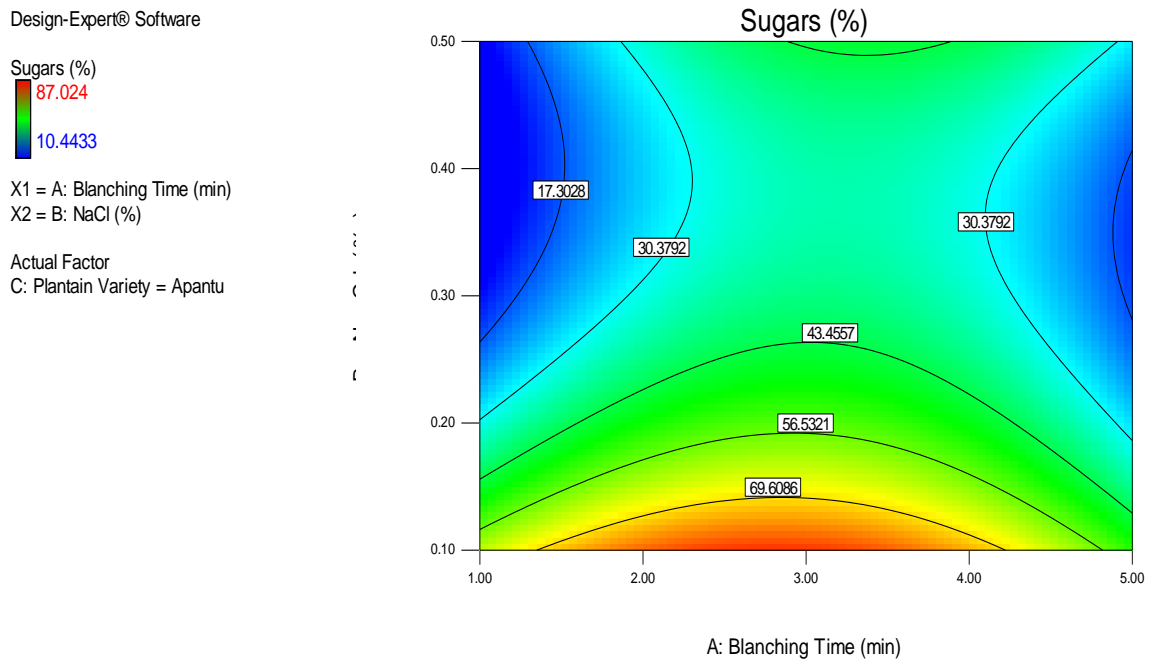


Figure. 4.1 Effect of blanching time and NaCl treatment on the sugar response in vacuum packaged peeled ‘*Apantu*’ plantain after 30 days of storage.

The sugar response was however minimal at 1 min blanching with 0.30 % to 0.50 % NaCl treatment and at 5 mins blanching with 0.30 % to 0.40 % NaCl treatment. This indicated that the shelf life of unripe *Apantu* variety of plantain could be prolonged when blanched at 1 min and vacuum sealed in 0.50 % NaCl solution.

As shown in Fig 4.2 for the ‘*Apem*’ plantain variety, the total sugar response was minimal at 5 mins blanching followed by sealing in NaCl solution with concentrations ranging from between 0.10 % to 0.40 %. From table 4.3 above, the least sugar response was observed for *Apem* plantain samples blanched at 5 mins and vacuum sealed in 0.30 % NaCl solution before storage. This indicated the shelf life of unripe *Apem* plantain could be prolonged under these pretreatment conditions prior to vacuum packaging.

Design-Expert® Software

Sugars (%)



X1 = A: Blanching Time (min)
X2 = B: NaCl (%)

Actual Factor
C: Plantain Variety = Apem

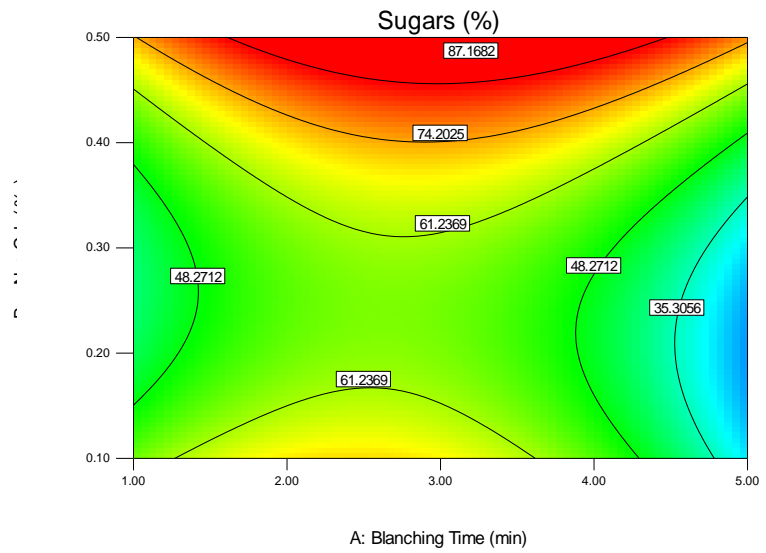


Figure. 4.2: The effect of blanching time and NaCl treatment on the sugar response in vacuum packaged peeled 'Apem' plantain after 30 days of storage.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Blanching time and NaCl treatment had no significant (at 5% significance level) effect on the sugar response of vacuum packaged sealed unripe plantain. However, plantain variety as well as the interaction of blanching time and NaCl treatment had a significant effect on the sugar response of the vacuum packaged peeled plantain.

Generally, sugar response ranged from 10.44 % to 87.02 % after 30 days of storage. The least sugar response was observed for Apantu plantain steam blanched for 1 min and vacuum sealed in 0.50 % NaCl solution. This indicated the most suitable blanching time and NaCl treatment for prolonging the shelf life of unripe peeled Apantu plantain.

On the other hand, blanching for 5 min and treatment in 0.30 % NaCl solution were found the most suitable conditions for prolonging the shelf life of unripe peeled Apem plantain prior to vacuum packaging.

5.2 Recommendation

Treatment conditions that resulted in the least sugar response could be exploited in prolonging the shelf life of unripe plantain. Moreover, further studies should be conducted with the suitable conditions found in this study for an extended storage duration. Also, the study should be repeated for other varieties of plantain.

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APPENDICES

Appendix 1.0: ANOVA for the sugar response of vacuum packaged peeled plantain

Analysis of variance table					
Source Model	Sum of Squares	df	Mean Square	F Value	p-value
	7323.07	8	915.3838	11.41073	0.0004
A-Blanching Time	56.43926	1	56.43926	0.703544	0.4212
B-NaCl Treatment	33.52973	1	33.52973	0.417965	0.5325
C-Plantain Variety	1444.159	1	1444.159	18.00219	0.0017
AB	645.6995	1	645.6995	8.048975	0.0176
AC	231.3495	1	231.3495	2.883889	0.1203
BC	4329.169	1	4329.169	53.9653	< 0.0001

Appendix 2.0: Experimental Design Summary

Study Type	Response Surface	Runs	19
Initial Design	Modified Distance	Blocks	No Blocks
Design Model	Quadratic		

Factor	Name	Units	Type	Low Actual	High Actual	Low Coded	High Coded	Mean	Std. Dev.
A	Blanching Time	min	Numeric	1	5	-1	1	2.74	1.71
B	NaCl Treatment	%	Numeric	0.1	0.5	-1	1	0.28	0.18
C	Plantain Variety		Categoric	Apantu	Apem			Levels:	2
Response	Name	Units	Obs	Analysis	Minimum	Maximum	Mean	Std. Dev.	Ratio
Y1	Sugars(RT)	%	19	Polynomial	10.4433	87.024	49.36	21.25	8.33

Appendix 3.0: Final equation for model in terms of coded factors

$$\begin{aligned}
 \text{Sugars(RT)} &= \\
 &49.54408 \\
 &-2.15279 * A \\
 &-1.54029 * B \\
 &10.40351 * C \\
 &7.612578 * A * B \\
 &-4.33425 * A * C \\
 &17.60198 * B * C \\
 &-25.3115 * A^2 \\
 &24.11219 * B^2
 \end{aligned}$$

Appendix 4.0: Final equation for model in terms of actual factors

Plantain Variety	Apantu
Sugars(RT)	=
	79.01157
	33.34859 * Blanching Time
	-514.489 * NaCl Treatment
	* Blanching Time * NaCl
	19.03144 Treatment
	-6.32788 * Blanching Time^2
	602.8048 * NaCl Treatment^2
Plantain Variety	Apem
Sugars(RT)	=
	60.0154
	29.01433 * Blanching Time
	-338.469 * NaCl Treatment
	* Blanching Time * NaCl
	19.03144 Treatment
	-6.32788 * Blanching Time^2
	602.8048 * NaCl Treatment^2

Appendix 5.0: Response surface plot for sugar response of peeled vacuum packaged *Apem* plantain

Design-Expert® Software

Sugars (%)

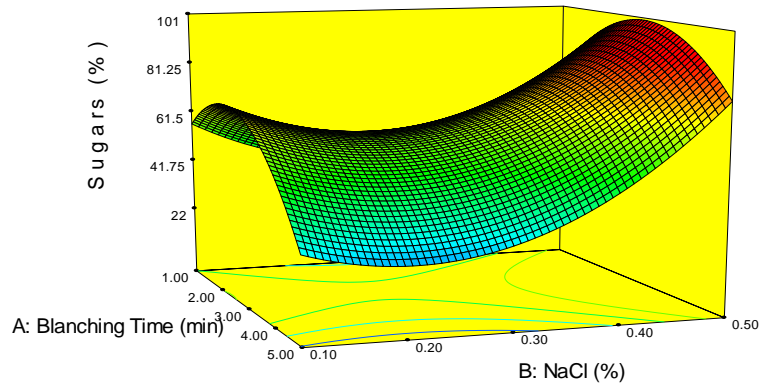


X1 = A: Blanching Time (min)

X2 = B: NaCl (%)

Actual Factor

C: Plantain Variety = Apem



Appendix 5.0: Response surface plot for sugar response of peeled vacuum packaged *Apantu* plantain variety

Design-Expert® Software

Sugars (%)



X1 = A: Blanching Time (min)

X2 = B: NaCl (%)

Actual Factor

C: Plantain Variety = Apantu

