EFFECTS OF BLANCHING CONDITIONS ON THE QUALITY CHARACTERISTICS OF PLANTAIN FLOUR

BY

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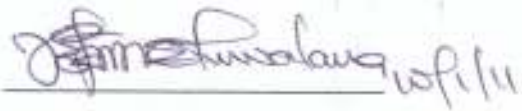
CERTIFICATION

This is to certify that this project work was carried out by **OLUWAFEMI, GBENGA ISAAC, MATRIC NO (FST/05/7045)** of the Department of Food Science and Technology, Federal University of Technology, Akure, Ondo State.



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DEDICATION

This project is dedicated to Almighty God who is the source of all good success. His grace was sufficient for me throughout my MTECH programme at FUTA. My parent can never be left out, Mr and Mrs Oluwafemi, I pray that you will live long to reap the fruit of your labour.

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ABSTRACT

The effect of blanching conditions on the proximate, mineral composition, functional and pasting properties of flour produced from plantain (*Musa AAB*) was investigated in this study. Mature green plantain fruits (*Musa AAB*) obtained from the International Institute of Tropical Agriculture (IITA), Ibadan were washed, peeled and sliced into cylindrical pieces of 2 mm thickness. Blanching was carried out on different samples at 60, 80 and 100^{0}C for 5min, 10min and 15min at each temperature. This was then followed by oven drying at 65^{0}C for 24 hours. Cooled samples were milled into flour, sieved, packaged into polyethylene bags for subsequent analysis. The flour obtained was analysed for proximate composition, functional properties, pasting properties, microbiological analysis and sensory evaluation of 'amala' made from the reconstituted plantain flour using a 9-point Hedonic scale. Results showed that blanching and dehydration processes had a significant effect ($p< 0.05$) on the proximate composition, pasting properties and functional properties of the flours; as well as on consumer acceptability of amala obtained from the flours. The Control had higher protein content (5.59%) but lower carbohydrate content (84.51%) compared to all the blanched samples. Also, sample UPB_{80-5}, UPB_{80-10} and UPB_{80-15} had a fat content of 1.90, 2.41 and 2.16%, respectively which were also significantly lower ($p< 0.05$) than the Control (2.63%). There was no significant difference on samples blanched at 60^{0}C for 10 and 15 minutes on Phosphorous, Iron and Potassium contents but further increase in blanching temperature led to a significant difference ($p < 0.05$) in all the minerals

when compared with the Control except for iron that ranged between 0.12 – 0.14%. The pasting properties of the flour including peak viscosity, final viscosity, setback viscosity and pasting time of blanched samples were significantly different ($p< 0.05$) from each other and from the unblanched Control. All blanching treatments did not show any significant difference in water and oil absorption capacity compared to the Control except for bulk density, solubility and swelling power. Low blanching temperature (60°C) was preferred for taste and texture, while samples blanched at 80°C however identified as best in colour. Blanching at 100°C had a significant effects ($p < 0.05$) on bacterial, mould and yeast counts.

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CHAPTER ONE

INTRODUCTION

1.1 Plantain

Plantain (*Musa parasidiaca*) (Stover and Simmonds, 1987) is an important staple food in Central and West Africa which along with bananas provide 60 million people with 25% of the calories (Wilson, 1987). Nigeria produces about 2.11 million metric tonnes annually (FAO, 2004). However, about 35 – 60% post harvest losses had been reported and attributed to lack of storage facilities and inappropriate technologies for food processing (Olorunda and Adelusola, 1997) . When processed into flour, it is used traditionally for the preparation of gruel which is made by mixing the flour with appropriate quantities of boiling water to form a thick paste. (Mepba *et. al.*,2007). Pere –Sira (1997) had also indicated the use of plantain flour as a component of baby food.

Processing of plantains into flour is limited as most plantain foods are eaten as boiled, fried or roasted (Tortoe *et al.*, 2008). A major draw-back for commercial availability of plantain flour is because the flour undergoes enzymatic browning degrading the colour of the flour which is one of the most important attributes of food (Tortoe *et al.*, 2008). The browning potential in various fruits and vegetables has been shown to be directly related to the ascorbic acid level, polyphenol content, the polyphenol oxidase (PPO) activity or a combination of these factors (Golan *et al.*, 1977; Walter and Purcell, 1980).

Blanching plays an important role on plantain enzymes such as pectinesterase, chlorophyll oxidase, peroxidase, polyphenol oxidase (Alvenainen, 1996). A major draw back for commercial availability of plantain flour is because the flour undergoes non-enzymatic browning degrading the colour of the flour which is one of the most important attributes of food. Therefore, dehydration methods such as hot-air blanching and osmo-dehydration are employed to remove water and limit enzymatic and non-enzymatic browning in foods (Tortou, *et al.*, 2008).

Plantain flour is sometime dark due to the action of enzymes. Improvement over the traditional method of processing had been reported. Blanching the plantain pulp at 60, 80 and 100^{0}C for 5, 10 and 15 minutes followed by draining and drying at 65^{o}C for 48 hours resulted in production of a more whitish flour. The chemical and nutritional composition of both ripe and unripe plantain have been investigated (Maud, 1991; Watt and Merill, 1975). There are reported high levels of micronutrients such as carotenes (pro-vitamin), ascorbic acid and minerals, particular calcium, potassium and phosphorous (Ketiku, 1973).

The functional properties are very important in determining the level of its utilization as ingredient formulation in food product development (Tasneem *et al.*, 1982). Blanching had been reported to have variable effects on functional properties of plantain flour (Fagbemi, 1999).

Pasting properties is an important index in determining the cooking and baking qualities of flour (PBIP, 1995). Studies have been conducted on the pasting properties of plantain soy flour mixes (Abioye *et al.*, 2006).

High setback value which is an important component of pasting properties of starch is associated with a cohesive paste and has been reported (Oduro *et al.*,2000) to be significantly present in domestic products such as pounded yam, which requires high setback, high viscosity and high paste stability. Setback value may be considered as an important parameter in reconstituted plantain flour (Adeniji and Tenkouano, 2008).

1.2 Objectives of this research are to:

a) prepare unripe plantain flour using different blanching temperature and blanching time combinations before drying,

b) investigate the effect of varying the blanching temperature and time on proximate, functional, microbiological, sensory quality and pasting properties of plantain flour.

1.3 Justification for this research is that:

a) the goal of food security in africa will not be achieved until the strategy for increased food production is completed with an improved processing method, the results identify better conditions for producing plantain flour.

CHAPTER TWO

LITERATURE REVIEW

2.1 Historical Background of Plantain

The early chronology of the spread and cultivation of bananas and plantains is still primarily a matter of conjecture. In Oceania, the earliest agriculture has been dated at around 8000 years BC. It is in this region that plantain derived from Musa species of the Australimusa series. Their cultivation is best described as a form of "proto-agriculture". They are gathered (rather than planted) from the wild by hunters.

Some 4000 years BC the earliest cultured and agricultural links between South East Asia and Oceania are speculated (Yuen, 1993). This is thought to have included the introduction of various crop plants. Subsequent introductions particularly of ABB and AAB types from the Philippines region are thought to have occurred during the Polynesian migrations. The relatively recent arrival and spread of bananas and plantains is sub-saharan Africa had profound effects on the regions subsequent development, and is a subject of much speculation drawing. Much of this relates to the cultivar diversity in different areas. In East Africa, in particular in the highland areas, cultivation is based on AA and AAA varieties, some unique to the region. Across equatorial Africa AAB plantains of various sorts dominate (Smith, *et al.*, 2008). Indonesian Voyagers are known to have had direct links with Madagascar and the coast of Africa from around, the 5th century AD.

2.2 Plantains in Traditional Agricultural Systems

Compare to other crops grown in traditional agricultural systems, plantain require relatively little land preparation, care and maintenance. This combined with

the comparatively high yields obtained mean that they are considered the cheapest (in terms of effort) of the starchy food staples to produce (Karikari, 1984). Among other characteristics that make plantains so well suited to traditional agriculture, the most obvious is their large size. This enables planting to be broadly spaced giving an undercapony spacious enough for other crops and the access needed to care for them The semi-perennial nature of the plant means that once established a field may be productive for many years. In East Africa fields of highland plantain may be virtually permanent lasting 50 years with high levels of mulching, although this situation is changing due to both population growth and disease pressure. In such a system the plantain field may be maintained as a mono-crop with annual crops being cultivated separately and around it (Wilson, 1987).

The near continuous availability of harvestable bunches from an established area of plantains (Nweke, *et al.*,1988) can contribute to the year-round security of food or income This may be particularly important when local conditions, drought for example, create periods of food shortage when other crops are unavailable. Drought tolerance in AAB and in particular ABB types is thought to come from the balbisiana (B) component of the genome. While a range of varieties occurs within a particular region, for example in the Philippines, Papua New Guinea (Sharrock, 1990), ABB cultivars tend to be grown in the more arid areas.

2.3 The Cultural Importance of Plantain

Plantains play a major role in the nutrition, wellbeing and cultural life of millions of people, a role perhaps unappreciated by western consumers aware only of imported AAB plantain. At one level this cultural contribution is in the varied culinary uses to which different types of plantain may be put. As plantain is harvestable year round consumption is generally of freshly harvested fruit.

Technologies of processing for storage are on the whole poorly developed although of potential importance, particularly in absorbing production "gluts" Variety may influence the manner of cooking, for example, in Cameroon in West Africa "French" plantains tend to be boiled and "Horn" plantains fried. However, in a Cameroonian restaurant one may also be offered the further choice between ripe (and thus sweet) or unripe (and thus starchy fried) "Horn" plantains. Cooking (and dessert types may also be roasted, boiled or steamed. (FAO, 1989).

The dietary importance of bananas and plantain is probably greatest in Africa (Karikari, 1980) where the social and cultural impact of their arrival has been described as greater than that of metallurgy. Easier to grow and in a greater range of environments and being more productive than the previous staple foods, plantains contributed to a complex demographic process, described as the Western Bantu expansion. As this contribution has attempted to show, the growing of plantains has a historical, geographical and cultural richness equal to any of the world's major crops. The importance plantains have for millions of people is beginning to achieve the recognition it merits. This is reflected in the increasing research effort being devoted to the crop. The world is faced with growing populations and decreasing food security

in its poorer regions. Research on bananas and plantain has an as yet barely tapped potential to help meet the challenges. Although, the most evident post-harvest losses are registered at the producer level in enclave sites during the rainy season in developing countries as previously estimated by FAO (1989).

2.4 Economic and Social Impact

Plantain (AAB) as well as other cooking bananas (AAB and ABB), East Africa cooking bananas, beer bananas (AAA) and desert banana (AAA) belong to the Musa genus.

Plantains are grown in more than 120 countries, in backyards or in mixed cropping systems by smallholders, and occasionally in monoculture (FAO, 2004). The total production is about 64 million tonnes with 23 percentages being the AAB plantains. The most prevalent combination of mixed cropping systems is cultivating plantains with coffee and cocoa. The data on the production and the consumption of plantain and other cooking bananas in some producing countries.

Table 2.1: Main Producing and Consuming Countries of Plantains and other Cooking Bananas

Countries	Yearly Production (x 1,000 tons)	Consumption (kg/Person/Year)	Plantain Calories Consumption (Calories/Person/Day)
Africa	600	67	111
Burundi	1000	81	195
Cameroon	1000	81	194
Coted'Ivoire	1530	49	112
Congo	1800	–	–
Nigeria	2150	91	222
Uganda	1350	–	–
Rwanda			
Tanzania	2463	82	197
Latin America	960	–	–
Colombia	600	70	135
Ecuador	580	–	–
Venezuela	105	–	–
Peru			
Bolivia	1150	66	115

Source: FAO (1989)

According to FAO (1989), about 70 percent of plantains and other cooking bananas are used for human consumption while 8 percent are used for animal feed. Post-harvest losses and transformed quantities in the world are 11.5 percent and 11 percent respectively.

2.5 Different Species of Plantain

For production purposes, bunch type and plant size characteristics are used to differentiate between plantain cultivars. In general, the morphology of the bunch is used for classification. These include;

1) **French Plantain:** In this cultivar type, inflorescence is completed at maturity (many hands consisting of many rather small fruits followed by inflorescence axis covered with persisting hermaphrodite flowers and male flowers, the male bud is large and persisted).
2) **French Horn Plantain:** Here, inflorescence is incomplete at maturity (hands consisting of large fingers followed by hermaphrodite flowers).
3) **False Horn Plantain:** In false horn plantain inflorescence is incomplete at maturity (hands consisting of large fingers followed by few hermaphrodite flowers).
4) **Horn Plantain:** Inflorescence is incomplete (few hands consisting of few but very large fingers; no hermaphrodite flowers and no male inflorescence; inflorescence axis is terminated by a tail or a deformed glomerule).

Plantain bunches are stunted by low temperatures at initiation and its prices depend more on grade than on total mass, (Irizarry *et al.,* 1991).

2.5.1 Harvesting

The stage of maturity for harvesting the fruits depends on the market for which it is intended and is determined in terms of the marketable life required. Harvesting begins 9 to 12 months after planting. The bearing plant is cut, and the bunch 3 to 4 months old, is harvested when 1 or 2 finger tips of the first hand start yellowing, (Ogazi, 1996). Care has to be taken that the bunch does not drop on the ground when the main plant is cut. The whole of the pseudostem and foliage of the main plant should be cut and spread over the soil as mulch to prevent weevils from living and multiplying on the intact pseudostem.

In some countries farmers harvest less mature fruits, even for local markets, because they have cash-flow problems and harvest soon as the ripening room operator will accept the fruit (Thompson and Burden, 1995). The initiation of ripening in climacteric fruits such as plantains is marked by a rapid rise in respiration rate of the fruit to a peak, after which the rate gradually falls as ripening progresses. During ripening the fruit softens, starch is converted to sugars, the skin colour changes from green to yellow; they lose their astringency and develop characteristics flavour.

2.5.2 Major plantain production zones in Nigeria

Nigeria is the largest producer of plantain in West Africa with annual production of about 2.4 million metric tones. It is mostly obtained from the southern states comprising Edo, Delta, Ondo, Rivers, Cross River, Akwa-Ibom, Imo, Abia, Ogun, Oyo, Osun, Anambra, Enugu and Lagos (Ogazi, 1996).

Plantain is one of the most important carbohydrate food items in West and Central Africa. Among the advantages of commercial production of plantain in Africa are low gestation period, possibility of making several harvests from one planting and low harvesting and processing costs.

2.6 Distribution, Marketing and Uses of Plantain in Nigeria

Studies of plantain marketing have shown that plantain fruit are subjected to adverse conditions during handling and transportation (Olorunda and Tung, 1985; Ferris, 1992; and Olorunda and Adelusola, 1997). Rough handling, splitting, vibration, abrasion, compression, impact and late delivery affect plantain quality during distribution. The results are post-harvest losses. Neither the total magnitude of post-harvest losses nor the extent to which it is avoidable are reliably known. The post-harvest distribution system of plantain is shows that plantain transportation throughout West Africa is by road, usually in open or partially closed vehicles. Fruit are packed in bunches or hands and stacked without any form of protection. Small scale wholesalers and retailers take plantain to more distant markets using Lorries and trailers. Plantain is usually harvested green and firm, but ripening often commences during hauling and transportation (Adelusola, 1992). As fruit ripen they become more susceptible to damage which leads to high losses (George, 1981).

Karikari, (1980) reported that all methods of transporting plantain in Ghana (transporting whole bunches stacked in trucks, smaller vehicles or on top of buses) result in extensive abrasion and subsequent blackening of fruit peel and damage to the

pulp. In Nigeria, the post-harvest distribution and marketing of plantain is inefficient. Adelusola (1992) observed that plantains bound for distant markets are gathered from farm-gate and village markets and then taken to collection centres for packaging operations. Unfortunately, the activities of the handlers in the packing sites often increase fruit deterioration. Fruit are packed into sacks which lack structural integrity and mechanical strength. The careless attitude of handlers is due to lack of adequate training and supervision.

Plantain marketing in Nigeria provides no protection for fruit from damage, dehydration and other detrimental factors. Usually, plantains are sold in open market under conditions that favour high moisture loss. This accelerates ripening and deteriorations (George, 1981). Currently, there are no established standard for quality and quantity in plantain transportation and marketing.

2.6.1 Composition and uses of plantain

The proximate chemical composition of plantain is shown in Table 2.2. The protein content of plantain pulp is low (2.0 – 2.5%), though not as low as that of cassava which is 1.0 – 1.5% (Marriott and Lancaster, 1983). Plantain contain less sugar and more starch than banana when compared at equivalent stages of ripeness. Plantain is richer in vitamin A and C than banana. There is no or less toxic substance in plantain fruit. The high level of physiological active amines; serotonin (5 – hydroxyl tryptamine), dopamine (3, 4 dihydroxy phyenylethlamine) and norepinephrininic is not considered a problem as serotonin is rapidly removed from

circulating plasma, so that plantain ingestion is not accompanied by elevated serum serotonin levels (Marriott and Lancaster, 1983).

The range of different uses of plantain shows that its preparation depends on ripeness and traditional cooking practice; it can be cooked unripe, ripe or overripe; either boiled, fried, baked or roasted. Plantain can be eaten alone or with stew, soup, sauce or cooking oil and ripe plantain can be eaten raw. Plantain can also be used in the snack food industries. Most plantain is sold as fresh fruit in the local marketing system in Nigeria. Although there are some export trades of plantain to Europe and U.S.A. Processed products made from plantain in Nigeria include fried chips and Dodo-Ikire (fried mash of over-ripe plantain). Industrial processing of plantain fruit is not really established although there is a potential if good products can be developed.

Medical data (anonymous) concerning plantain and banana shows that the carbohydrate from these fruit is readily absorbed by the human digestive system. This explains the inclusion of plantain in the diet of people suffering from intestinal disorder, and the widespread use of banana fruit in baby foods. "Amala", a solid paste prepared from dried unripe plantain flour is usually eaten by diabetic patients in the western and eastern parts of Nigeria. The presence of resistance (indigestible) starch in unripe plantain and banana and low sugar level could be a reason for this purpose. Plantain also have some anti-ulcerogenic effect. Dry (roasted) unripe plantain is usually eaten against aspirin-induced ulceration. The high level of potassium in plantain and banana is also thought to be beneficial to people suffering from headache. (Ogazi, 1996)

Table 2.2: Physicochemical Composition of Plantain Fruit

Component	Unripe	Ripe
Water	57.63%s	66.4%
Sugar	1%	15%
Food energy	124.8 kcal	119 kcal
Protein	2.0%	2.5%
Fat	0.3 – 0.4%	0.4%
Carbohydrate	35%	31.2%
Fibre	3.0 – 4.0%	0.4%
Ash	0.8 – 1.0%	0.9%
Calcium	7mg/100g wet basis	7mg/100g wet basis
Magnesium	33mg/100g wet basis	–
Phosphorous	35mg/100g wet basis	30mg/100g wet basis
Iron	0.5mg/100g wet basis	0.7mg/100g wet basis
Sodium	–	5mg/100g wet basis
Potassium	350mg/100g wet basis	385mg/100g wet basis
Vitamin A	1.2mg/100g wet basis	–
Vitamin C	20mg/100g wet basis	20mg/100g wet basis
Thiamine	0.05mg/100g wet basis	0.06mg/100g wet basis
Riboflavin	0.05mg/100g wet basis	0.4mg/100g wet basis
Niacin	0.7mg/100g wet basis	0.6mg/100g wet basis
Sulphur	15mg/100g wet basis	–

Table 2.2: Physicochemical Composition of Plantain Fruit (Continued)

Alanine	122mg/100g dry basis	118mg/100g dry basis
Aspartic acid	179mg/100g dry basis	214mg/100g dry basis
histidine	75mg/100g dry basis	85mg/100g dry basis
Glutamic acid	165mg/100g dry basis	302mg/100g dry basis
Leucine	132mg/100g dry basis	151mg/100g dry basis
Methionine	24mg/100g dry basis	45mg/100g dry basis
Praline	103mg/100g dry basis	123mg/100g dry basis

Source: Marriott and Lancaster, (1983)

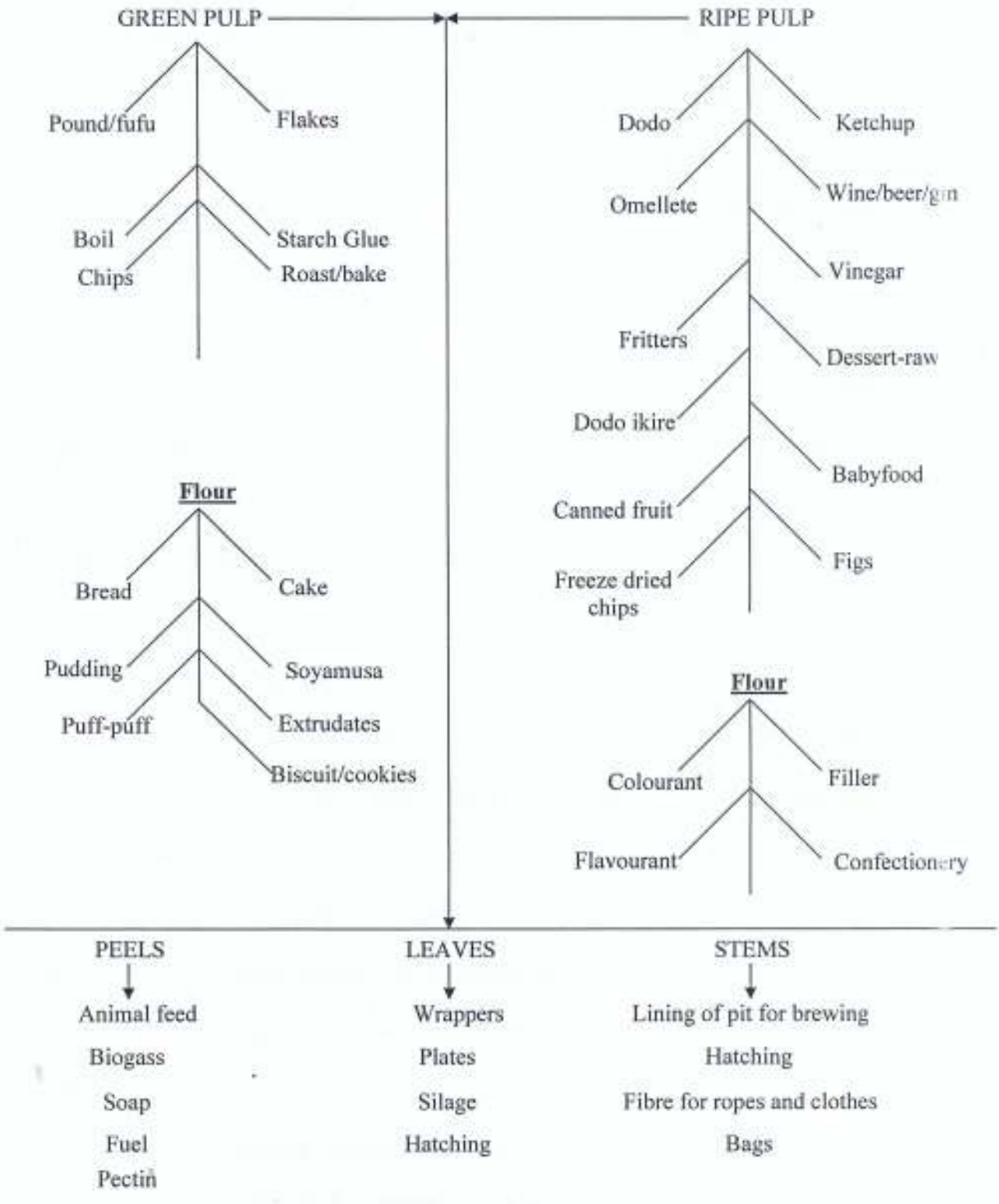

Fig. 2.1: Different Uses of Plantain and Banana
Source; Ogazi, (1996)

2.7 Ripening

Ripening is a physicochemical process peculiar to fruit. It is a metabolic process that occurs from the later stage of growth and development through the early stages of senescence. Ripening process is accompanied by a series of biochemical changes that result in characteristic aesthetic and/or food quality manisfed by changes in composition, colour, texture, flavour and other sensory attributes (Shewfelt, 1986).

Ripening is also among the different factors of post-harvest quality because market-life is limited with the onset of ripening. Handling hazards also increase with ripening/softening of fruit. Therefore, ripening rate of a fruit is an index of it's market potential. Pre-climacteric period (PCP) of a fruit is the time–span between harvesting and the onset of the climacteric ethylene spike which triggers ripening (Marriort, 1983; Wills *et al.* 1984) and is a useful physiological index of fruit storage-life.

2.7.1 Mechanisms of ripening

Ripening results from the breakdown of tissue cellular integrity. The major metabolic reaction taking place during ripening is respiration. Respiration is the oxidative breakdown of complex materials present in the cell cytoplasm such as starch, sugar and organic acids into simpler molecules, such as CO_2, amino acids and water with the concurrent production of energy and other molecules necessary for synthetic reactions (Wills *et al.*, 1984). Thus, ripening is interplay of degradative and synthetic reactions.

The onset of ripening can be delayed, though not indefinitely and once started ripening cannot be reversed. The initiation of ripening is marked by an increase in

ethylene production and respiration and the process becomes irreversible once endogenous ethylene has reached a threshold level (McGlasson, 1985). Respiration supplies the energy for the synthesis of enzymes involved in ripening reactions, (Shewfelt, 1986) and ethylene triggers a synchronized ripening response and physiological changes that occur during ripening (Biale and Young, 1981). The changes serve as a signal to an end in the life of a fruit at the cellular level.

2.7.2 Factors affecting ripening and potential market-life of plantain fruit;

2.7.2.1 Maturity

Maturity at harvest is a vital factor affecting ripening (Ferris *et al.*, 1993). The more mature plantain fruit is at harvest, the faster the rate of ripening. False horn plantain harvested after 100, 90 and 80 days had a ripening period of 11, 15, and 22 days respectively. Although, the ripening period is extended as the maturity at harvest is reduced, there is also a reduction in fruit yield.

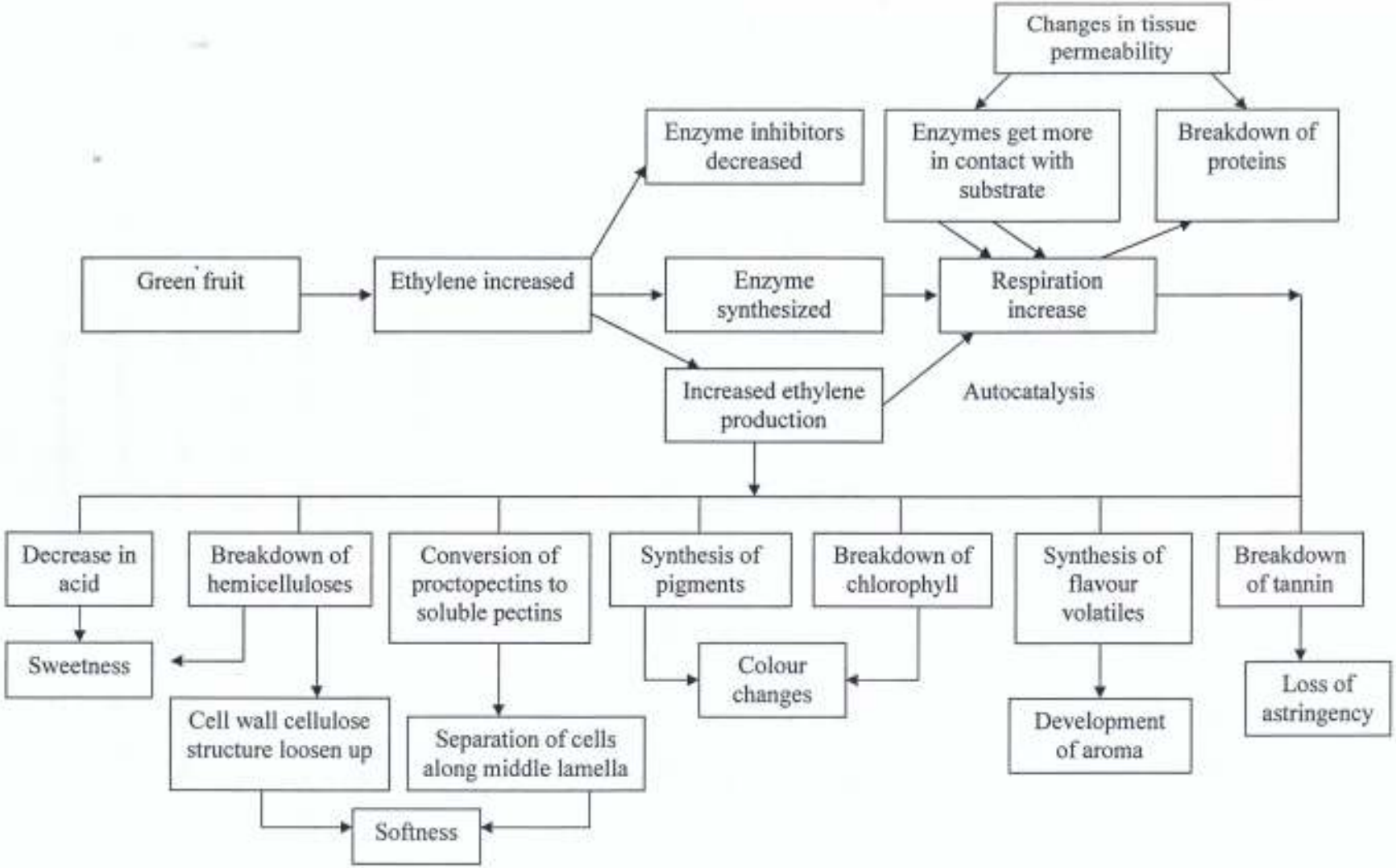

Fig. 2.2: Mechanism of Fruit Ripening

Source: Beautista (1990)

2.7.2.2 Rate of respiration

The major physiological reactions of detached plant tissues are senescence and weight loss (Marriott, 1983); respiration rate being an excellent indicator of metabolic activity in the tissue. During ripening, tissue use the energy accumulated by the plant before harvest. This causes depletion in the stored energy of harvested plant. Reducing the rate of respiration after harvest is a means of lowering the rate of senescence. During respiration, plants take in oxygen and expire carbondioxide and heat; thus condition increases the affinity of ethylene (ripening hormone) to the receptor site (Wills *et al.*,1984). The higher the rate respiration in a fruit, the faster the rate of ripening and the lower the potential market-life.

Rate of respiration depends on transpiration (Stomata index, cuticle structure and surface area to volume ratio) temperature and relatively humidity (Beautista, 1990). Respiration rate in fruit gradually declines with maturity and continues to fall even after the fruit is picked until the climacteric rise, in the case of climacteric fruit.

2.7.2.3 Temperature

Temperature extremes affect both the rate of ripening and quality of fruit. At temperatures below 12°C many tropical fruit including Musa fruit suffer from chilling injury while at temperatures above 35°C plantain and banana develop the physiological disorder termed "boiled" fruit whereby the pulp becomes soft but peel remains green (Blackbourn *et al.*, 1990). The relationship between ripening and temperature is related to fruit respiration. Generally, high temperature increases the rate of respiration and hence reduces marketable life.

Variations in temperature coefficient depend on fruit maturity at harvest so that proportionality was constant irrespective of maturity at harvest; though for a particular immature banana bunch (Giant Cavendish), the Pre-climateric period was greater at 17°C than at 15°C or 13°C. It was observed that at a wider temperature range (15 – 35°C) a logarithmic relationship occurred between temperature and Pre-climateric period (PCP) such that;

$$\text{Log } g = MT + C$$

where g = PCP; T = Temperature; C = Constant which depends on storage humidity and diffusion coefficient , M= maturity period

The above reports indicate that a reduction in temperature caused a proportional increment in PCP irrespective of fruit physiological maturity (Marriott, 1980) deduced that the observed constant (C) corresponded to a 100% increase in PCP for a 6.5°C decrease in temperature. Lowering temperature decreases both ethylene production and tissue response to ethylene, so that at lower temperature longer exposure to a given ethylene concentration is required to initiative ripening.

2.7.2.4 Oxygen and carbondioxide

Oxygen and carbondioxide play major roles in physiological reactions during ripening. Manipulation of O_2 and CO_2 brings about a modified atmosphere which can extend the ripening period of fruit. Stover and Simmonds (1987) established that ripening of plantain and banana could be delayed for several weeks when ventilated in a gas mixture depleted of O_2 (< 21%) and enriched in CO_2 (> 0.03%). They also observed that ripening occurred at ambient temperature when small amounts of

ethylene were introduced into a 1 – 5% oxygen banana storage atmosphere. They concluded that oxygen affects ripening by mediating ethylene production as production of ethylene requires oxygen.

All the enzyme associated with ripening are aerobiotic. The composition of O_2 and CO_2 influence the affinity of receptor sites for ethylene. Oxygen is involved in the oxidation of a metal component of the proteinaceous ethylene binding site and also affects the initial step of glucose breakdown or acts as the terminal electron carrier so that absence of O_2 results in enhancement of glycolytic enzymes. CO_2 has been reported to compete with ethylene at the metallic receptor site (Gowen, 1995).

2.7.6.5 Sunlight

The pre-climacteric period of bananas with or without illumination was reported that a 50% reduction in PCP when fruit were exposed to full sunlight for 6 days in comparison with a Control. This was independent of fruit maturity and was greatest when exposure was immediately after harvest (Burdon *et al.*, 1991). It is assumed that light triggers opening of stomata.

2.7.2.6 Ventilation

High rates of ventilation accelerate ripening by causing fruit desiccation. Restricted ventilation reduces moisture loss in plantains, but has an opposite effect of rapid progress of ripening once initiated (Karikari, 1980). That is if a fruit starts to ripen, restricted ventilation enables a build-up of ethylene which then triggers the ripening of other fruit. It is better to increase ventilation in transit by limiting bulk density (compactness) and by regulating loading pattern.

2.7.2.7 Physical stress

Karikari (1980) observed, though without statistical evidence that damages inflicted during handling and transportation of plantains was a major contributing factor to early ripening and post-harvest losses. Wounding increased the rate of respiration, Shewfelt (1986) and hence ripening rate. Physical integrity of fruit prior to ripening affects the ripening process as well as the quality of the ripe fruit. Physical/peel injury causes cellular disorganization of fruit and in some cases like abrasion injury, removal of moisture barrier membrane resulting in higher water loss and hence shorter ripening period.

2.7.3 Ripening in plantain: physiological characteristics

Harvested plantain fruit remain a living entity, undergoing respiration and transpiration. In order to sustain metabolism after harvest, energy is made available through respiration. As this is no longer being supplied by the mother plant, the fruit source its energy and water needs from its own resources. Plantain shows a gradual decrease in respiration but the initiation of ripening is accompanied by a marked ethylene production and respiration rise. The ripening process is irreversible once endogenous ethylene reaches a threshold level.

The post-harvest physiology and biochemistry of plantain is similar to desert banana of the AAA group in colouration, softening and hydrolysis of starch to sugar (Stover and Simmond, 1987) though, the tissue softening and starch hydrolysis do not proceed as rapidly and completely as in bananas (Marriott, 1980). It has been shown

that plantain produces larger amount of ethylene during ripening and requires a higher temperature range for ripening than bananas (Stover and Simmond, 1987).

George (1981) reported that water stress caused by moisture loss affected the PCP of plantain more than any other factor. The rate of moisture loss from plantain depends on the amount of wax on the peel surface, cuticle organization and the number of functional stomata. Ferris *et al.* (1993) further observed that maturity affects both ripening period and mechanical strength of plantain fruit.

2.7.3.1 Mode of action of ethylene in fruit

Ethylene is an olefin gas, often described as a plant hormone, which is biologically active as trace levels (0.1 – 1.0 µl/L) (Yang and Hoffman, 1984). Ethylene acts in concert with other plant hormones (auxin, glibberelin, kinin and absicissic acid) to exercise control over plant growth and senescence (Wills *et al.*, 1984). All plant tissues are capable of producing ethylene, although the production rate differs for different tissues at different stages of maturity and senescence (Knee *et al.*, 1985). In some fruits, ethylene production peaks during ripening, while ripening in others is not accompanied by ethylene upsurge. The difference in reference to the production of ethylene during ripening can be used to divide fruit into two groups, climacteric and non-climacteric. Climacteric fruits exhibit a surge of ethylene production at the onset of ripening. Non-climacterics maintain a steady rate of ethylene production during ripening. Non-climacteric fruit show an increase in the rate of respiration on exposure to ethylene, but this falls when the ethylene is removed. Consequently, a rise in respiration may occur more than once in non-climacteric fruit but for climacteric fruit

the process is autocatalytic, that is, once ripening has started it cannot be stopped as the presence of ethylene, triggers further production of ethylene. The magnitude of climacteric depend on the concentration of ethylene applied in non-climacteric while it is independent on climacteric fruit.

Ethylene (based or induced) changes the permeability of fruit mitochondrial membrane, thus, facilitating movement of ATP, and initiating several reactions including increased respiration (Yang and Hoffman, 1984). Although, the specific metabolic site affected by ethylene is still obscure, it is known that ethylene binds to specific receptor(s) site to form a complex which then triggers ripening and other gene expressions. The binding of ethylene to a receptor takes place reversibly at a site containing a metal, probably Copper (Yang, 1981). The affinity of the receptor for ethylene is increased in the presence of oxygen and decreased in the presence of carbon-dioxide. In climacteric fruit (e.g. banana), ethylene concentration rise beyond the threshold level during the onset of ripening. It is believed that unripe fruit lack the ability to synthesize ethylene and so has low concentration of ethylene. The involvement of autocatalysis in the ripening of climacteric fruits indicates that any treatment which can prevent ethylene from reaching the triggering concentration would delay ripening.

The physiological reactions that occur in plantain during ripening are responsible for the following changes.

(a) Change in Colour: Degradation of chlorophyll and appearance of carotenes (Biale and Young, 1981)

(b) Increase in Rate of Respiration: Ethylene and flavour production (Wills *et al.*, 1984)

(c) Increase in Tissue Permeability: Softening of tissues-hydrolysis of pectin substances, (Biale and Young, 1981); Breakdown of the cell wall pectin substance in plant cells which acts as cementing agents giving rigidity to the plant.

(d) Hydrolysis of Carbohydrate into Sugars: A higher conversion of starch to soluble sugars occurs in the pulp, thus creating a differential change in osmotic pressure which induces water to be withdrawn from the peel into the pulp. Pulp softens and peel losses tugor and get thinner (Banks and Joseph, 1991) which results in easy separation of peel from pulp, a characteristics of ripe plantain fruit. Sugar level of plantain (unlike banana) increases continuously during ripening, hence precise control of the stage of ripening prior to utilization is a critical factor in processing of plantain.

(e)Breakdown of Organic Acid: Increase in malic acid and decrease in fermic acid (Marriott and Lancaster, 1983; Stover and Simmond, 1987).

(f) Decrease in Amino Acids: Protein synthesis

(g) Loss of Weight (George, 1981; Ferris, 1992): Transportation of metabolites and transpiration

(h) Loss of Mechanical Strength (Banks and Joseph, 1991; Ferris, 1992): Disruption of calcium bridges as a result of reduction in calcium level.

2.7.4 Mechanical damage and fruit quality

Wounding affects tissue quality and integrity immediately and the effects also accumulate until the end of senescence or when the fruit is consumed. One of the physiological responses to fruit damage is the generation of wound ethylene. If this ethylene is sufficient to trigger the climacteric, the fruit will immediately start to ripen. The capacity to heal wounds is drastically reduced after harvest and most wounds which occur after harvest remain unprotected (Wills *et al.*, 1984; Beautista, 1990).

Consumer's perception of banana quality embraces size, colour, blemish free, maturity, wilting, physical integrity and cultivar. The internal quality is of less significance (Marriott, 1980) as it cannot be judged before purchase. This equally applies to plantain. Preservation of the physical integrity of fruit is therefore necessary in order to attract consumers.

Physical integrity also affects the physiological status of fruit. Damage increases transpiration rate, thereby inducing shriveling, wilting and loss of weight (Ferris, 1992). Injuries resulting from mechanical damage create opportunities for microbial infection, increase the rate of metabolism (deterioration) and cause immediate loss of edible material because of the need to trim off damaged portions during cooking. Damage causes the disorganization of the cell membrane, leading to the release of enzymes which break down lipids (fatty acids) in the mitochondrial membrane (Beautista, 1990). Fatty acids are utilized in wound-respiration, production of stress ethylene and heat. Respiration and ethylene speed up ripening, heat increases

the temperature of the surrounding tissues leading to further increase in respiration (Beautista, 1990).

Ferris, (1992) reported that abrasion increased the rate of ripening in plantains and cooking bananas by almost 50% and caused the desiccation of pulp and peel during ripening. The oxidation of tannin plant's tissue or exposure of similar materials to air in the injured tissues turns the portion brown (Schoorl and Holt, 1983) which disfigures the fruit with unsightly marks resulting in the loss of visual quality. Severely damaged fruit have little or no food use.

2.7.5 Plantain post-harvest loss control

According to FAO (1989), post-harvest loss is the main contributing factor towards the food scarcity in Africa. Increasing food production to offset post-harvest loss is the common solution, however this is inefficient and devising methods to prevent loss is a vital means to achieving real food security. Against the background of rising population and falling production rate per capita, there is a clear need to ensure that food losses are minimized. In the light of the present high losses of harvested crops (Olorunda and Tung, 1985; FAO, 1989), it seems the goal of food security in Africa will not be achieved until the strategy for increased food production is complemented by a programme of loss prevention through improved harvesting, transportation, handling, packaging, storage, processing and marketing. However, this fact has been largely ignored and most investment on agricultural research has been on production.

The problem with reliance on production alone is that inadequate storage, inefficient distribution and lack of modern processing techniques which are common in Africa result in large harvest being transformed into large wastage and low crop value. Considering the fact that most emphasis on improving the farming system have been production based, further research is required in the area of loss prevention and utilization. It is likely that devising methods to prevent loss will be cheaper and less risky than increasing production to offset potential loss. It is for this reason that this research was carried out to find methods of preventing post-harvest losses of Musa fruit through adequate handling and processing.

As with all fruits, a series of physiological changes leading to senescence and death commences in plantain after harvest. Although, these activities cannot be stopped, they can be slowed down in order to extend the use of fruit. Some techniques which extend the storage life of plantains include one or a combination of the following.

(a) Reducing Storage and Transportation Temperature: Low temperatures (above 15°C) reduce the rate of respiration and other metabolic activities in fruit.

(b) Use of Polyethylene Bag (PEB): Either alone or in combination with low temperature and/or ethylene absorbent (Olorunda and Aworh, 1984). PEB prevents mechanical damage by reducing friction or rub between fruit surfaces. Ethylene absorbent (potassium permanganate) absorbs up ethylene produced by the fruit preventing ripening trigger.

(c) Controlled/Modified Atmosphere: Increasing CO_2 and diminishing O_2; evacuated FEB (hypobaric storage) and surface coating/wax: Tal-prolong and

semperfresh (Hussein *et al.*, 1985; and Ferris, 1992). These conditions have been said to reduce respiration and ethylene production rate.

(d) Use of Chemicals like Gibberelic and GA3, GA4 (George and Marriott, 1983): To inhibit ethylene production rate.

(e) Use of Fungicides like thiabendazole and benomyl to excert anti-microbial effect

(f) Radiation

The adoptions of these methods are not economically feasible in the present marketing system of West Africa. One of the most pressing post-harvest problems of plantain is the hauling of the fruit from farm-gate and transportation to urban markets. These operations are associated with delays and mechanical damages which can result in severe loss. (Adelusola, 1992). As a solution to the problem of Musa fruit transportation, Karikari (1980) suggested airfreight as a means of avoiding transport delay, and effects of rough roads.

One economic approach to reducing losses would be to manipulate pre and post-harvest conditions in such away as to maximize the fruit's resistant to bruising. Olorunda and Aworh (1986) has increased the firmness of sliced plantains with calcium chloride ($CaCl_2$). Use of $CaCl_2$ has also extended the storage life of apples, tomatoes and pear (Greirson, 1987). Farmers could also process their produce for alternative uses particularly when there is transportation and or market failures for fresh produce.

2.8 Handling and Storage of Plantain

Post-harvest handling including storage of fruits has in recent times become very important, mainly due to the realization that handling practices after harvest can cause huge losses of produce that required large inputs of labour, materials and capital to grow (Aworh and Olorunda, 1984) Various authors have estimated that up to 80% of fresh produce are lost during postharvest handling.

In many of the developing countries where the production of many fruits are not only seasonal but their consumption is removed in time and space from the point of major production, post-harvest losses could assume considerable economic and social importance.

In the post-harvest handling of produce, the harvested fruits should be regarded as "living structures". It is easy to accept the fact that a produce is a living, biological entity when it is attached to the growing parent plant in its agricultural environment. But even after, the produce is still living as it continue, to perform metabolic reactions and maintain physiological systems which were present when it was attached to the plant.

An important feature of plants and therefore of fruits is that they respire by taking up oxygen (O_2) and giving off carbondioxide (CO_2) and heat. They also transpire hence losing water.

Respiration and transpiration continue after harvest and since the produce is now removed from its normal source of water, photosynthesis and minerals. The produce is now dependent entirely on its own food reserves and moisture content (Ogazi, 1996). The aim of storage or post-harvest technology therefore is to explore

how are can control or minimize the rate at which the above processes take place in order to achieve the desired objectives. This can be ameliorated by using adequate handling and transportation methods and increasing the shelf-life of fruits by retarding their physiological processes that take place during storage (Olorunda and Aworh, 1984).

2.8.1 Packaging

Improvement in packaging has contributed greatly to more efficient marketing of fresh fruits. Advantages of packaging are; less damage and wastage, higher market returns; retention in the market for competitive price and availability of the produce to the consumer over a longer period and of farther distance.

In developing regions, most fruits are packed for handling, transport and storage in sacks, baskets or boxes made form paper or wood, many of which have been previously used for other manufactured goods.

Baskets made from flexible materials, at a cottage industry level have the advantages of cheapness and convenience over other types. These containers do have adequate compression strength but may lose their integrity and even shape during handling process. This often results in mechanical injury to the perishables (Ogazi, 1996).

2.8.2 Storage

The shelf-life of plantain reduces considerably under tropical conditions if the fruits are not adequately stored. In view of this, storage of plantain is imperative in order to obtain maximum benefit from plantain production, processing and utilisation.

The quality of plantain mainly changes as a result of continuation of metabolic activities after harvest and in storage.

Plantain can be harvested and stored for variable periods in a pre-ripe condition and ripening can be induced more or less at will by suitable control of storage conditions. In general, to extend shelf-life of plantain, physiological processes can be retarded as follows:

(a) Controlling storage temperature

(b) Use of ethylene

(c) Use of chemical treatments

(d) Use of controlled and modified atmosphere and hypobaric stable

(e) Use of irradiation for fruit preservation

It has been observed that different *Musa* groups respond differently to water stress. It is possible that the differences in the susceptibility to this factor and hence green life, may offer a means for extending the storage life of plantain.

Freshly harvested green plantain starts to ripen in about 7 days, reaching full ripeness within two days at room conditions of relative humidity of 90% and temperature of about 30°C. If stored in refrigerator chambers, they remain green for twelve days, but the products made from them were of poor quality.

Additionally, post-harvest treatment of plantain with crop protection chemicals also assist in increasing shelf-life of stored products (Ogazi, 1996). Plantain treated with gibberellins by dipping for 30 minutes in solutions of various concentrations, containing a wetting agent and allowed to dry for 15 minutes before packing, have stored for longer periods.

The storage of plantain is also extended by packaging in sealed polythene bags with ethylene absorbent (Ferris, 1995). The objective of using polythene bags is to maintain high humidity to enable endogenously produced ethylene to accumulate, thereby resulting in accelerated ripening (Wainwright and Burdon, 1991).Though, plantain has been observed to release a remarkable level of ethylene, inclusion of an ethylene absorbing compound such as potassium permanganate on an inert carrier in the storage of plantain can reduce its accumulation considerably.

Pasting Properties of Plantain Flour

Peak viscosity is the maximum viscosity developed during or soon after the heating portion of the test in RVU

Breakdown: peak viscosity minus trough viscosity, in RVU

Final viscosity: viscosity at the end of the test, in RVU

Setback from trough: final viscosity minus trough viscosity in RVU

Peak time: time at which the peak viscosity occurred in minutes

Pasting temperature: temperature where viscosity first increases by at least 2 RVU over a 20 seconds

Trough viscosity: is the period which is commonly accompanied by a breakdown in viscosity

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

Mature green and healthy plantain (*Musa*, AAB group) bunches were obtained from the International Institute of Tropical Agriculture (IITA), Oyo Road, Ibadan. with acceptable appearance for consumption (Dadzie and Orhard, 1997). All reagents used were of analytical graded.

Preparation of plantain flour

The fruits were brought to the laboratory at green (unripe) stages which were subsequently defingered. The fingers were washed, hand-peeled and manually sliced into cylindrical pieces of 2mm thickness. Blanching was carried out on the sliced samples in hot water at 60°C, 80°C and 100°C. For each temperature chosen, the timing was varied for 5, 10 and 15 minutes and dried in the air oven at 65°C (24/hrs), while the unblanched samples (Control) were also dried using the air oven at the same temperature of 65°C/24hrs (Baiyeri and Ortiz, 2000).

The dehydrated products were milled in a hammer mill to produce flour which passed through a 150µm screen. The plantain flour obtained was packaged in polyethylene bags labeled and stored at room temperature for further analysis. The flours were coded as follows:, $UPB_{60^{-}15}$ = Unripe plantain blanched at 60°C for 15 minutes, $UPB_{60^{-}10}$ = Unripe plantain blanched at 60°C for 10 minutes, $UPB_{60^{-}5}$= Unripe plantain blanched at 60°C for 5 minutes, $UPB_{80^{-}15}$ = Unripe plantain 80°C for 15 minutes , $UPB_{80^{-}10}$ = Unripe plantain blanched at 80°C for 10 minutes, $UPB_{80^{-}5}$ = Unripe plantain blanched at 80°C for 5 minutes, $UPB_{100^{-}15}$ = Unripe plantain blanched

at 100°C for 15 minutes, UPB_{100-10} = Unripe plantain blanched at 100°C for 10 minutes, , UPB_{100-5} = Unripe plantain blanched at 100°C for 5 minutes, $UPUB_c$ = Unripe plantain un-blanched (Control)

Reconstitution of Plantain Flour

The overall ratio of flour to water used in plantain amala preparation was 1:3 (w/v). This was thoroughly stirred with a wooden spatula over a hot plate heater to produce a thick dough called "amala" (Adeniji and Tenkouano, 2008).

3.2 Analytical Procedures

The proximate analysis of the samples were determined as follows:

3.2.1 Moisture content determination

Sample (2g) was accurately weighed into a pre-weighed cleaned weighing/drying dish provided with easily removable lid. The un-covered dishes with its lid open were placed in a well-ventilated oven maintained at 103°C. After 16 hours, the lid was replaced and transferred into a dessicator at room temperature to cool, after cooing for about 30minutes, it was re-weighed as quickly as possible, replaced with sample and lid open to the oven for another 2 hours. The steps were repeated until a constant weight was achieved according to AOAC (1990). The loss in weight was recorded as moisture content for each of the sample.

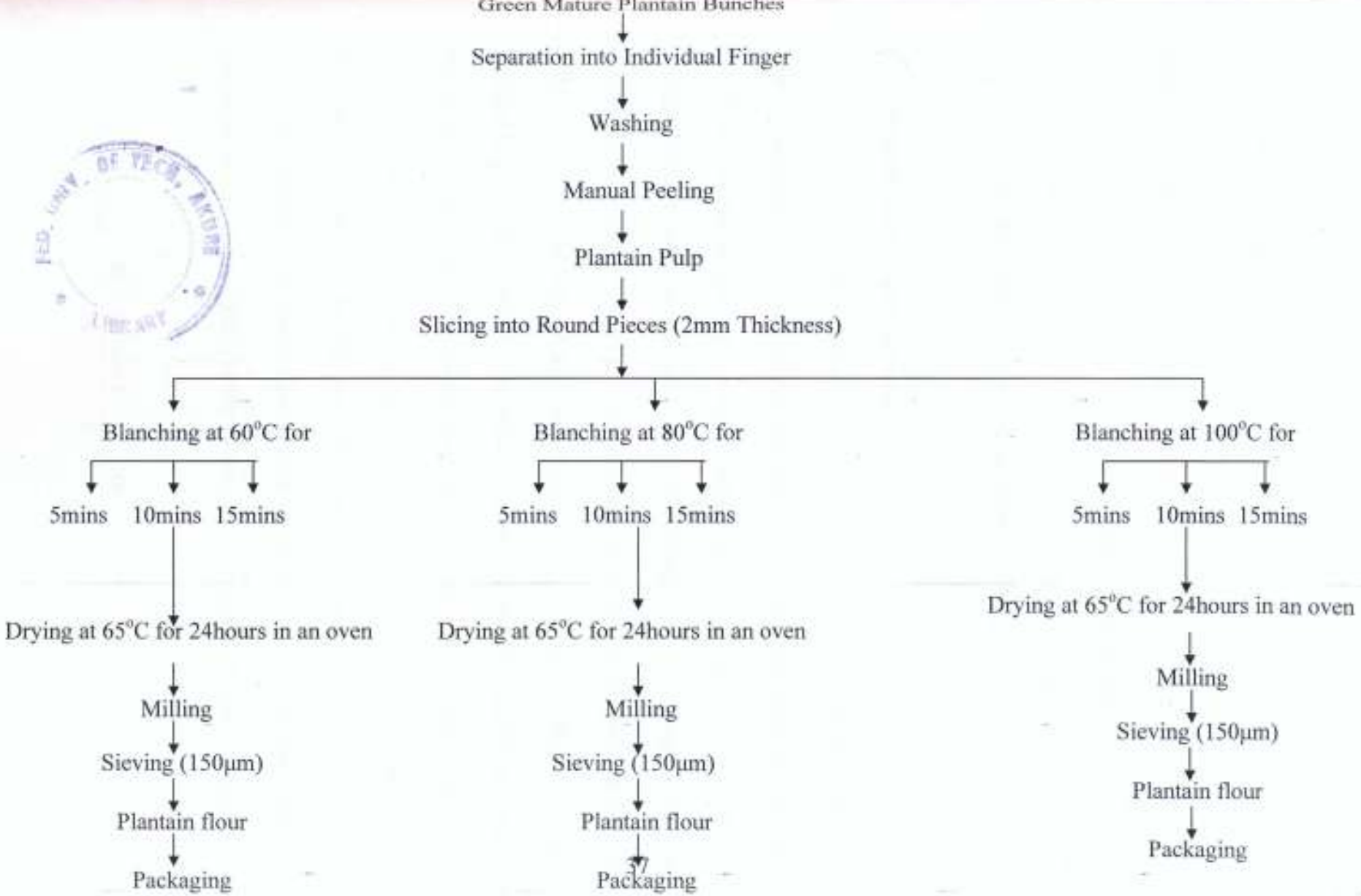

Figure 3.1: Flow Chart for the Production of Plantain Flour, (Ogazi, 1991)

$$\% \text{ moisture content} = \frac{M_1 - M_2}{M_1 - M_0} x \frac{100}{1}$$

Where M_0 = Weight in g of dish and lid

M_1 = Weight in g of dish, lid and sample before drying

M_2 = Weight in g of dish, lid and sample after drying

M_1- M_0 = Weight of sample prepared for drying

3.2.2 Protein content determination

Two grammes of the samples each was weighed into Kjeldahl flask, known grams of catalyst mixture was added and 5ml of conc. sulphuric acid was also added. The flask was heated until the samples were digested i.e. until a clear colour was formed. The mixture was allowed to cool. The digests were made up to 50ml with distilled water. 5ml of 2% boric acid was transferred into 100ml conical flask (receiving flask). The boric acid trapped down the ammonia vapour from the digest. 3 drops of indicator was added to each of the solution connected with the distillation apparatus with delivery tube dipping below the boric acid solution. 5ml of each of sample was pipette into the distiller followed by the addition of 10ml of 40% sodium hydroxide. The joints were tight and distilled about 50ml into the receiving flask.

The distillate was then titrated against 0.01M HCl and the protein content was calculated according to AOAC (1990) for each of the sample as follows in triplicate:

$$\%g \text{ Nitrogen} = \frac{M \; x \; T \; x \; 0.014}{W} x \frac{V_1}{V_2} x \frac{100}{1}$$

M= Molarity of acid

T= Titre value

V_1= volume of digest

V_2= volume of digest used

W= weight of sample

% protein = % nitrogen x 6.25

3.2.3 Ash content determination

Crucibles were washed, dried and cooled. 5g of each of the sample was weighed into the already weighed crucible. The crucible and the content were transferred into the muffle furnace which was slowly increased from 200°C – 550°C for 6 hours. The sample was ashed until it became whitish in colour. After this, the crucibles which were in triplicate were removed from furnace and cooled in a dessicator for about 1 hour i.e. allowed to cool to room temperature and weighed. The percentage ash content of each of the sample was calculated in triplicates according to AOAC (1990).

$$\%\ ash\ content = \frac{Weight\ of\ ash}{Weight\ of\ sample} x \frac{100}{1}$$

3.2.4 Fat content determination (Soxtec system HT2)

Each of the thimble was loaded with 2g of the sample and pluged with cotton wool. The thimbles were dried and inserted into the soxtec. HT. The extraction cups were dried and weighed (with boiling chips) 25ml of the solvent (hexane) was added into each cup and were also inserted into the soxtec. HT. Extraction lasted for 15minutes in

boiling position and 30minutes in rinsing position. The solvent was evaporated; the cups were released and dried at 100°C for 30minutes. The cups were cooled in a dessicator and weighed; this was done for each of the sample in triplicate according to AOAC (1990) and calculated as follows;

Weight of cup with the extracted oil = W_3

Weight of the empty cup = W_2

Weight of sample = W_1

$$\% \ fat = \frac{W_3 - W_2}{W_1} x \frac{100}{1}$$

3.2.5 Crude fibre determination (Trichloroacetic acid method)

The crude fibre content of any food (raw or processed) is indicative of the indigestible matter or roughage in the food. The method involves defating the food materials. Hydrolyzing the protein and carbohydrate in the food using a mixture of acids. Apparatus: 600ml long beaker; porcelain crucible; muffle furnace; crude fiber refluxing apparatus and filter paper (Whatman No 4.11cm) Reagents: Distilled water; methylated spirit; hexane; TCA Reagent: Mix 500ml glacial acetic acid, 450ml H_2O and 50ml conc. HNO_3. Dissolved 20g trichloroacetic acid in this mixture.

According to AOAC (1990) the samples were defatted with hexane. 1g of defatted sample was weighed into 600ml beaker, 100ml TCA reagent were added, boiled and refluxed for 40minutes beginning from the time boiling starts, the flask was removed and slightly cooled, filtered and the residue were washed six times with hot distilled H_2O and once with methylated spirit. The filter paper together with the samples

were transferred into a porcelain crucible, dried in the oven at 100°C over night which was latter cooled in a dessicator and weighed (Weight A). It was ashed in a muffle furnace at 600°C for 6 hours cooled in a dessicator and weighed (Weight B).

Loss in weight during incineration was equivalent to the amount of the crude fibre. This was calculated for each of the sample in triplicate as follows;

$$\%\ crude\ fiber = \frac{(Weight\ A) - (Weight\ B)}{Sample\ weight} x \frac{100}{1}$$

3.2.6 Carbohydrate content determination

The carbohydrate content was calculated by adding up the percentage moisture, protein, ash, fat and crude fibre and subtract from 100 %.

Carbohydrate = 100 – (% M.C + % C. P. + % A. C. + % F. C. + % C. F)

3.3 Mineral content determination

The nutritionally important minerals in plantain flour samples were determined from solution obtained as follows: 1.5g of the sample was pre-ashed by putting the sample in a dish and heating gently on a Bunsen burner in a fume-cupboard until the cleaned mass had ceased to emit smoke. It was transferred to muffle furnace and ashed at 550°C.

Heating was continued until the carbon got burnt-off. The crucible plus ash was transferred to a dessicator to cool after which 10 mls of 0.1 mol solution was added to the content in the crucible to break up the ash. It was then filtered through acid washed Whatman filter paper into 100ml volumetric flask containing diluted acid solution.

Atomic Absorption Spectrophotometer was used for the analysis of the following metals: sodium, calcium, potassium, magnesium, copper, zinc, manganese, iron and phosphorous were determined by using the standard for each metal.

The instrument was switch on and lamp for each metal was fixed. All the metals analyzed for use hallow cathode lamps and air acetylene flame. The standard for each metals were aspirated into the flame as well as the samples and their respective concentration were read for each sample, while the absorbance of the standards were noted.

Calculation:

$$ppm = AX \frac{F_v}{W_t} XD$$

A = Concentration of sample or absorbance

W_t = Weight of sample used

F_v = Final volume of sample extract or the digest weight of sample used

D = Dilution factor

3.4 Functional Properties of Plantain Flour

Functional properties have been defined by Sathe *et al.* (1982) as those characteristics that govern the behaviour of nutrients in food during processing, storage and preparation as they affect food quality and acceptability. Some of the important functional properties that influence the utility of most starchy staples such as plantain include the drying characteristics, water absorption capacity, oil absorption capacity,

emulsion capacity, emulsion stability foam capacity, foam stability swelling capacity and viscosity.

3.4.1 Water and oil absorption capacity

Flour sample (2g) was mixed with 20ml distilled water for water absorption and 20ml of oil for oil absorption in Moulinex blender (Model de PC3, France) at high speed for 30 seconds. Samples where then allowed to stand at 30°C for 30 minutes then centrifuged at 10,000rpm for 30 minutes. The volume of the supernatant in a graduated cylinder was noted. Density of water was taken to be 1g/ml and that of oil was determined to be 0.93g/ml.

Means of triplicate determinations were reported.

$$\%\,WAC = \frac{Vol.of\ distilled\ water\ absorbed}{Weight\ of\ sample\ used} x \frac{100}{1}$$

$$\%\,OAC = \frac{Vol.of\ oil\ absorbed\ x\ 0.93g/ml}{Weight\ of\ sample\ used} x \frac{100}{1}$$

Source: Sathe *et al*, (1982)

3.4.2 Emulsion capacity and stability

Emulsion capacity was determined as described by (Sathe *et al.*, 1982). One gramme of each of the samples was weighed and blended with 5ml distilled water in a 100ml beaker by stirring at 1000rpm for 5 minutes on a magnetic stirrer. 5mls of oil was added to the mixture and the stirring continued for another 5 minutes. The mixture was transferred into graduated tubes (10ml) heated in water bath at 85°C for 30 minutes with

occasional stirring and cooled for 15 minutes in water bath maintained at 25°C. The solution was finally centrifuged at 3500rpm until the volume of oil get separated from emulsion was constant and expressed as grams of oil emulsified by 1g flour.

$$\% \, E.C = \frac{Volume \ of \ the \ emulsified \ layer}{Sample \ weight} x \frac{100}{1}$$

Emulsion stability was studied following the methods described by (Beuchat, 1977). Flour sample (4g) was dispersed in distilled water (100ml) then 100ml of the peanut oil was added at the rate of 12.5ml per second while blending. Each sample was blended in a Moulinex blender at high speed for additional 60 seconds and transferred into a 250ml graduated cylinder, volumetric changes in foam, oil and aqueous layers were recorded after 3hrs.

Triplicate measurements were made and average results were taken.

3.4.3 Bulk density

The bulk density was determined as described by Narayana and Narasinga, (1984). This was determined by first weighing the measuring cylinder, while each of the sample was determined by weighing sample 50g sample into 100ml graduated cylinder, tapping the cylinders ten times against the table in the laboratory and expressing the final volume as (g/ml).

$$B.D = \frac{Weight \ of \ measuring \ cylinder \ and \ sample - Weight \ of \ the \ measuring \ cylinder}{Volume \ occupied \ by \ the \ sample} x \frac{100}{1}$$

3.4.4 Least gelation concentration

The modified procedure of Coffman and Garcia (1977) was used to determine gelation. Increasing flour concentration were suspended in 10ml distilled water in test tube and heated in a boiling water bath (Gallenkamp) for 1 hour. The tubes were rapidly cooled to 4°C. The least gelation concentration (%) was taken as the minimum concentration when the sample in an inverted tube did not slip.

3.4.5 Determination of swelling power and solubility

The dried sample (1g) was weighed into 100ml of conical flask, 15ml of distilled water was added and shaked for 5 minutes at low speed. It was then transferred into water bath and heated for 40 minutes at 80°C with constant stirring, latter transferred into a pre-weighed centrifuge tube follow by the addition of 7.5ml distilled water, centrifuged at 2200rpm for 20 minutes, while the supernatant was decanted into a pre-weighed Can and dried at 100°C to constant weight and finally cooled in a dessicator and weighed.

Each of the samples was calculated in triplicate

Calculation:

1) Weight of the empty Can = A
2) Weight of the Can + dried supernatant = B
3) Weight of solubles = A – B
4) Weight of empty centrifuge tube = D
5) Weight of centrifuge + sediment = E
6) Weight of sediment = E – D

$$Swelling\ power = \frac{Weight\ of\ sediment}{Sample\ weight - weight\ of\ solubles}$$

$$\%\ Solubility = \frac{Weight\ of\ soluble}{Weight\ of\ sample}\ x\ \frac{100}{1}$$

Source: Leach *et al.*, (1959)

3.5 Pasting Properties of Plantain Flour

Pasting properties of flour was characterized using Rapid Visco Analyzer (RVA model 3C Newport Scientific PTY Ltd., Sydney) as described by Delcour *et al.* (2000) and Sanni *et al.*, (2004). Three grams (3g) of sample was accurately weighed into a weighing vessel. 25ml of distilled water was dispensed into a new test canister. Sample was transferred onto the water surface in the Canister, after which the paddle was placed into the Canister. The blade was vigorously joggled up and down through the sample ten times or more until no flour lumps remained neither on the water surface nor on the paddle. The paddle was placed into the canister and both were inserted firmly into the paddle coupling so that the paddle is properly centered. The measurement cycle was initiated by depressing the motor tower of the instrument. The test was then allowed to proceed and terminate automatically.

3.6 Microbiological Examination

Plantain flours were examined for viable count of bacteria, coliforms, yeast and moulds using plate Count Nutrient Agar, MacConkey agar and potato dextrose agar, respectively. The pour plate method was used to enumerate the total number of viable microorganisms in the plantain flour. Serial dilution was done using normal saline to 10^{-3} dilution and 1ml of 10^{-3} dilution was added into each sterile Petri dish. Molten plate count agar was added into the plates, agitated and allowed to solidify and incubated at 37°C for 48hrs. The number of colonies counted on the plates taken into consideration the dilution factor.

The presence of Coliform was determined by inoculating plantain flour samples on McConkey agar and incubating at 37°C for 18hrs (Anderson and Hollorook, 1980). The presence of yeasts and moulds were enumerated by inoculating the serial dilution of plantain flour samples on potato dextrose agar. The plates were incubated at 25°C for 3 days (Harrigan and McCane, 1976).

3.7 Sensory Evaluation

A total of 10 – panelists drawn from Federal University of Technology Akure, Food Science and Technology Department assessed the sensory quality of the reconstituted plantain flour "amala". The sensory quality of amala made from each flour sample was measured on a standard nine-point hedonic scale. The panelists rated the amala samples for colour, taste and texture on a scale varying from 1 = dislike extremely to 9 = like extremely (Larmond, 1982).

Data Analysis

Determinations were carried out in triplicates and the error reported as standard deviation from the mean. Data were subjected to analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) at a significance level of 0.05

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Proximate composition

The effect of blanching temperature and time on the proximate composition of plantain flour shown in table 4.1 indicates that blanching at 60°C, 80°C and 100°C for 5, 10 and 15 minutes all had significantly ($p < 0.05$) lower moisture contents (6.28-6.70%) compared to the unblanched Control (8.63%). Increase in blanching temperature and time beyond 60°C and 5 minutes respectively did not show any significant reduction in moisture contents of the flour. The lower moisture content of the blanched samples tends to suggest that blanching aids the rate of drying of the plantain chips pulverized into flour. The high value of the moisture content of the unblanched Control is still within an acceptable limit for a stable shelf life as reported by Kayisu *et al.*, (1981).

The protein content of the blanched samples which were in the range (2.40-3.93%) across the blanching temperatures time were generally lower than the unblanched Control (5.59%) (Table 4.1). The higher the blanching temperature and time, the lower the protein content of the flour. The implication of this could be that some of the protein is either leached or denatured by the blanching process and duration. This was contrary to the observation of Fagbemi (1999) who reported that blanching had no effect on the protein content of the plantain flour. The least protein content was still within the range of values for plantain flour (2.0 – 2.7%) reported by Tagodoe and Nip, (1994).

The ash content of the unblanched Control (2.93%) was significantly higher ($p < 0.05$) compared to the treated samples, but increase in blanching temperature and time i.e. from 80°C to 100°C for 5 to 10 minutes had no significant difference ($p > 0.05$).

Table 4.1 showed that as the blanching temperature increases, the fat content reduces: UPB_{60-5} (2.24%), UPB_{80-5} (1.90%), UPB_{100-5} (1.70%), these values were lower significantly ($p < 0.05$) compared to the unblanched Control (2.63%). The lower level of fat in the treated samples give a higher probability of a longer shelf-life in terms of the onset of rancidity.

Table 4.1 also showed that the crude fibre of the treated samples were not significantly different ($p > 0.05$) from each other but differ from the unblanched Control.

The carbohydrate value of the blanched samples UPB_{60-5}, UPB_{80-5}, UPB_{100-5}, UPB_{60-10}, UPB_{80-10} and UPB_{100-10} were 89.04%, 89.94%, 90.52%, 88.51%, 89.62% and 90.22% respectively, these were not significantly different from each other but significantly ($p > 0.05$) higher than the unblanched Control, 84.51%

Table 4.1 showed that the caloric values of the treated samples were not significantly different from each other but were significantly different from the unblanched Control (384.33kJ). This could be as a result of the low carbohydrate content of the unblanched Control.

Table 4.1: Proximate composition of plantain flour blanched for 5, 10 and 15 minutes at 60, 80 and 100^{0}C

Sample	UPB_{60}			UPB_{80}			UPB_{100}			$UPUB_{CO}$
	5	10	15	5	10	15	5	10	15	
Moisture (%)	6.67±0.23^b	6.70±0.04^b	6.46±0.03^b	6.68±0.11^b	6.54±0.06^b	6.31±0.06^c	6.47±0.05^b	6.41±0.03^b	6.28±0.07^c	8.63±0.05^a
Protein (%)	3.93±0.28^b	3.91±0.07^b	3.35±0.05^c	3.72±0.08^c	3.42±0.09^a	2.59±0.04^e	3.60±0.06^c	3.15±0.06^c	2.40±0.11^d	5.59±0.04^a
Ash (%)	2.30±0.17^b	2.58±0.03^b	2.67±0.01^b	2.20±0.09^c	2.28±0.02^c	2.16±0.04^d	2.03±0.11^d	2.19±0.10^d	2.32±0.07^c	2.93±0.07^a
Fat (%)	2.24±0.08^b	2.54±0.05^a	2.25±0.05^b	1.90±0.02^c	2.41±0.06^b	2.16±0.05^c	1.70±0.04^d	2.24±0.01^c	1.92±0.01^d	2.63±0.03^a
Total crude Fibre (%)	2.49±0.38^b	2.45±0.03^b	2.68±0.03^b	2.25±0.02^c	2.27±0.03^c	2.66±0.02^b	2.16±0.04^c	2.17±0.05^c	2.55±0.03^b	4.27±0.06^a
Carbohydrate (%)	89.04±1.06^a	88.51±0.04^b	89.05±0.05^a	89.94±0.10^a	89.62±0.13^a	90.44±0.04^a	90.52±0.05^a	90.22±0.05^a	90.82±0.12^a	84.51±0.06^b
Energy (K cal)	392.26±2.96^a	392.79±0.29^a	390.08±0.38^b	391.93±0.64^a	394.09±0.27^a	391.77±0.72^a	391.95±0.32^a	393.86±0.64^a	390.35±0.12^b	384.33±0.15^c

Percentage carbohydrate by difference mean ± standard deviation for three determinations
The values other than moisture content are on a dry weight basis
Values in the same column with different letters in superscript are significantly different at $p < 0.05$
UPB_{60} = Unripe Plantain Blanched at 60°C for 5, 10 and 15 minutes
UPB_{80} = Unripe Plantain Blanched at 80°C for 5, 10 and 15 minutes
UPB_{100} = Unripe Plantain Blanched at 100°C for 5, 10 and 15 minutes
$UPUB_{CO}$ = Unripe Plantain Unblanched (Control)

4.2 Effect of blanching temperature and time on the mineral composition of plantain flour

Table 4.2 showed that increase in blanching temperature (60°C – 100°C) and time (5-15minutes) had a significant effect on some of the mineral composition of the treated samples; UPB_{100-5}, potassium (110mg/100g), UPB_{100-10}, calcium(405mg/100g) and UPB_{100-15}, magnesium(225mg/100g) which were significantly lower compared to the Control; potassium(210mg/100g) , calcium(535mg/100g) and magnesium(430mg/100g), while there was no significant difference in iron, manganese and copper values among the samples blanched at 60°C and 80°C for 5 and 10 minutes and from the unblanched Control. The low values in minerals at higher blanching temperatures and time could be due to leaching of nutrients into the blanching medium as reported by Ahenkora, *et al.*, (1996)

4.3 Effect of blanching temperature and time on the pasting properties of plantain flour

Table 4.3 show that blanching at 60°C, 80°C and 100°C for 5, 10 and 15 minutes had a significant ($p<0.05$) effect on peak viscosity, trough, breakdown and final viscosity. Peak viscosity, trough and breakdown reduced, compared to the unblanched Control (543.42RVU, 325.75RVU, 217.67RVU, 409.33RVU and 83.58RVU) respectively, but there was no significant difference in the peak time and pasting temperature which were ranged (4.53 - 4.91 minutes) and (79.93 - 83.23°C) respectively among the treated samples and when compared to the unblanched Control (4.52 minutes and 81.80°C) respectively. High setback at low blanching temperature could be as a result of pre-gelatinization of the starch in the flour which could lead to unattractive consistency of the gruel as reported by Ramteke and Eipeson (2000).

The high pasting temperature of the unblanched Control (81.80%) and that of the unripe plantain blanched at 60°C for 5 minutes could be as a result of the presence of strong bonding forces within the granules of flour as reported by Hoover (2001).

4.4 Effect of blanching temperature and time on the functional properties of plantain flour

Table 4.4 showed that increasing blanching temperature from 60°C – 100°C and time from 5 – 15 minutes had a significant effect on the water absorption capacity of the unripe plantain flour ranged between (115.50-125.50%) across the blanching temperatures and time. Samples (UPB_{100-15}) had the highest value of water absorption capacity (125.50%). The high value could be due to the separate forming expansible matrix in the flour and the high value of protein content as reported by Oates (1997) and Osundahunsi (2005). The oil absorption capacity of the treated samples was on the range 109.0-115.50% across the blanching temperatures and time but not significantly ($p < 0.05$) different from the unblanched Control.

The bulk-density of the treated sample; UPB_{80-5} (0.182g/ml), UPB_{100-5} (0.172g/ml), UPB_{80-10} (0.164g/ml), UPB_{100-10} (0.159g/ml) and UPB_{80-15} (0.140g/ml), UPB_{100-15} (0.140g/ml) all these were not significantly different from each other but differ from other treated samples and the unblanched Control (0.420g/ml). This is contrary to a report made by Tagogoe (1994) which showed that bulk density increased as a result of heat treatment of flour prior to drying.

The emulsion stability and capacity of the blanched samples; UPB_{80-5} (24.58% and 30.46%), UPB_{80-10} (20.04% and 25.00%), UPB_{80-15} (30.23% and 36.19%) respectively were significantly lower than the unblanched Control (41.23% and 39.84%) respectively across the blanching temperature and time. As blanching temperature and time increased,

emulsion stability and capacity of the samples also reduced. This could be as a result of heat of blanching as reported by Fagbemi (1999).

Table 4.4 show that swelling power and solubility of the blanched samples which were in the range (28.47% - 40.03%) and (3.77% - 4.69%), respectively were significantly ($p < 0.05$) lower than the unblanched Control (48.09%) and (5.89%) respectively across the blanching temperature and time. Increasing the blanching temperature and time had a significant effect ($p < 0.05$) on the samples.

The least gelation concentration of the unblanched Control (2.00%) is significantly lower ($p < 0.05$) compared to the treated samples; UPB_{60-5} (6.00%), UPB_{80-5} (4.00%) and UPB_{100-10} (6.00%) but the samples blanched at 60°C, 80°C, and 100°C for 15 minutes were not significantly different from each other. The values were still lower than that of the value reported by Fagbemi (1999).

4.5 Sensory properties of the reconstituted plantain "amala"

Table 4.5 show the sensory attributes of the reconstituted plantain "amala". The attributes rated by the panelist were taste, colour and texture. Sample UPB_{60-10} was scored best for taste but not significantly different ($p > 0.05$) from sample UPB_{60-15}. Sample UPB_{80-10} rated the best for colour. This may be due to the slight non-enzymatic browning that took place during drying (Tortoe *et al.*, 2009). The Control UPUBC rated best in terms of texture but not significantly different ($p < 0.05$) from the following samples: UPB_{60-5}, UPB_{60-10}, UPB_{60-15}.

4.6 Microbiological Quality of plantain flour

Table 4.6 showed that increasing the blanching temperature and time had a significant effect on the total count of bacterial, coliforms and mould/yeast in the plantain flour. The microbial count reduced as the blanching temperature and time increased when compared with the Control. Control sample had a higher total viable count, coliforms and mould/yeast count of (3.0, 1.0 and 4.0 cfu/g $x10^3$ respectively compared with the treated samples; UPB_{60-5} (2.0, ND and 3.5 cfu/g $x10^3$), UPB_{60-10} (2.0, ND and 3.2 cfu/g $x10^3$), UPB_{60-15} (1.0, ND and 1.4 cfu/g $x10^3$), UPB_{80-5} (2.0, ND and 2.4 cfu/g $x10^3$), UPB_{80-10} (1.5, ND and 2.2 cfu/g $x10^3$), UPB_{100-5} (1.4, ND and 2.0 cfu/g $x10^3$) respectively. The high mould/yeast count could be due to the high moisture content in unblanched Control.

Table 4.2: Mineral composition of plantain flour blanched for 5, 10 and 15 minutes at 60, 80 and 100^{0}C

Sample	UPB_{60}			UPB_{80}			UPB_{100}			$UPUB_{CO}$
	5	10	15	5	10	15	5	10	15	
Calcium (mg/100g)	690.0±10.00^a	585.0±5.0^a	700.0±20.0^a	595.0±15.0^b	525.0±5.00^b	485.0±5.0^{b,c}	420.0±10.00^c	405.0±5.0^c	405.0±50.0^c	535.0±75.00^b
Magnessium (mg/100g)	340.0±10.0^b	330.0±5.0^b	330.0±10.0^b	305.0±5.0^c	320.0±10.0^b	290.0±20.00^c	255.0±5.00^d	245.0±5.00^e	225.0±5.00^d	430.0±0.00^a
Potassium (mg/100g)	160.0±10.0^b	160.0±5.0^b	180.0±10.0^b	150.0±10.0^b	155.0±10.0^b	135.0±5.0^c	110.0±10.0^d	120.0±10.0^e	115.0±5.0^d	210.0±0.00^a
Sodium (mg/100g)	3.01±0.03^c	3.37±0.06^b	3.41±0.05^b	3.19±0.08^b	3.31±0.20^b	2.55±0.24^c	3.01±0.11^c	3.39±0.08^b	3.60±0.04^b	5.03±0.04^a
Manganese (mg/100g)	2.07±0.08^b	1.97±0.05^b	1.75±0.05^c	2.03±0.09^b	1.82±0.08^c	1.55±0.06^c	1.76±0.06^c	1.80±0.03^c	1.72±0.03^c	2.40±0.01^a
Iron (mg/100g)	0.13±0.00^b	0.17±0.04^a	0.13±0.00^b	0.12±0.00^b	0.13±0.01^b	0.12±0.00^b	0.13±0.01^b	0.13±0.01^b	0.13±0.00^b	0.13±0.00^b
Zinc (mg/100g)	0.05±0.00^a	0.05±0.00^a	0.05±0.00^a	0.04±0.00^b	0.05±0.00^a	0.04±0.00^b	0.05±0.00^a	0.05±0.00^a	0.04±0.00^b	0.05±0.00^a
Copper (mg/100g)	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.02±0.00^b	0.03±0.00^a
Phosphorus (mg/100g)	170.0±10.0^a	160.0±10.0^{ab}	175.0±5.0^a	170.0±10.0^a	155.0±25.0^b	155.0±25.0^b	160.0±10.0^{ab}	170.0±5.0^a	170.0±10.0^a	155.0±5.00^b

Values in the same column with different letters in superscript are significantly different at $p < 0.05$

UPB_{60} = Unripe Plantain Blanched at 60°C for 5, 10 and 15 minutes

UPB_{80} = Unripe Plantain Blanched at 80°C for 5, 10 and 15 minutes

UPB_{100} = Unripe Plantain Blanched at 100°C for 5, 10 and 15 minutes

$UPUB_{CO}$ = Unripe Plantain Unblanched (Control)

Table 4.3: Pasting properties of plantain flour blanched for 5, 10 and 15 minutes at 60, 80 and 100^{0}C

Sample	UPB_{60}			UPB_{80}			UPB_{100}			$UPUB_{CO}$
	5	10	15	5	10	15	5	10	15	
Peak Viscosity (RVU)	527.08±0.04^b	511.92±0.01^b	445.67±0.04^b	434.58±0.17^c	414.08±0.56^e	403.58±0.30^e	422.0±0.04^c	410.0±0.56^c	355.25±0.17^d	543.42±0.20^a
Trough (RVU)	335.92±0.01^a	304.67±0.01^b	291.08±0.54^b	288.92±0.43^c	276.92±4.60^e	235.83±2.09^g	257.33±0.49^d	248.92±0.04^d	263.33±0.31^c	325.75±0.32^a
Breakdown (RVU)	191.16±0.04^b	207.25±0.02^b	154.59±0.51^c	145.66±0.60^d	137.16±5.16^g	167.75±2.39^b	164.67±0.45^c	161.08±0.52^c	91.92±0.14^g	217.67±0.51^a
Final Viscosity (RVU)	434.92±0.01^a	407.75±0.03^b	374.92±0.05^b	353.50±1.25^c	366.50±0.21^c	302.75±0.07^d	343.75±0.39^d	320.42±0.10^g	355.92±0.40^c	409.33±0.10^a
Setback (RVU)	99.00±0.00^a	103.08±0.02^a	83.84.66±1.04^b	64.58±0.82^c	89.58±4.39^b	66.92±2.13^c	86.42±0.10^b	71.50±0.06^c	92.59±0.09^a	83.58±0.22^b
Peak time (minutes)	4.73±0.01^a	4.53±0.01^b	4.64±0.04^b	4.75±0.05^a	4.67±0.00^b	4.59±0.02^b	4.64±0.04^b	4.56±0.05^b	4.91±0.02^a	4.52±0.01^b
Pasting temperature (^{0}C)	82.65±0.00^{ab}	79.93±0.03^c	81.55±0.01^b	82.77±0.58^a	81.20±0.4^b	82.55±0.01^b	80.90±0.70^c	81.32±0.34^{ab}	83.23±0.03^a	81.80±0.10^{ab}

Values in the same column with different letters in superscript are significantly different at $p < 0.05$

UPB_{60} = Unripe Plantain Blanched at 60°C for 5, 10 and 15 minutes

UPB_{80} = Unripe Plantain Blanched at 80°C for 5, 10 and 15 minutes

UPB_{100} = Unripe Plantain Blanched at 100°C for 5, 10 and 15 minutes

$UPUB_{CO}$ = Unripe Plantain Unblanched (Control)

Table 4.4: Functional properties of plantain flour blanched for 5, 10 and 15 minutes at 60, 80 and 100^{0}C

Sample	UPB_{60}			UPB_{80}			UPB_{100}			$UPUB_{CO}$
	5	10	15	5	10	15	5	10	15	
Water absorption capacity (%)	120.50±0.50^b	118.50±0.50^b	115.50±0.00^b	123.50±1.50^a	123.50±0.50^a	123.50±0.50^a	125.50±0.50^a	125.50±0.50^a	125.50±0.50^a	124.50±4.50^a
Oil absorption capacity (%)	115.50±0.50^b	111.50±0.50^a	109.00±1.00^b	112.50±0.50^a	112.50±0.50^a	111.50±0.50^a	110.50±0.50^b	112.50±0.50^a	111.50±0.50^a	108.50±4.50^a
Bulk density (g/ml)	0.249±0.02^b	0.194±0.08^c	0.290±0.02^b	0.182±0.05^c	0.164±0.08^c	0.140±0.01^c	0.172±0.03^c	0.159±0.07^c	0.140±0.03^c	0.420±0.07^a
Emulsion stability (%)	29.83±0.27^b	26.82±0.50^b	31.07±0.00^b	24.58±1.41^c	20.04±0.29^c	30.23±0.35^b	18.48±0.09^d	12.03±0.07^d	20.25±0.10^c	41.27±0.51^a
Emulsion capacity (%)	41.12±0.28^a	30.45±0.72^c	36.68±0.37^b	30.46±0.62^c	25.00±0.11^e	36.19±0.32^b	27.03±0.12^c	17.86±0.17^d	24.14±0.18^c	39.84±0.19^a
Swelling power (%)	36.04±0.18^c	39.98±0.12^b	40.03±0.08^b	30.95±0.07^d	28.47±2.61^d	35.98±0.07^c	39.80±1.24^b	38.19±0.33^b	35.16±0.21^c	48.09±0.23^a
Solubility (%)	4.24±0.03^b	3.77±0.04^d	3.47±0.05^d	4.69±0.09^b	4.59±0.07^b	4.38±0.09^b	4.02±0.07^c	4.14±0.07^c	4.31±0.06^b	5.89±0.33^a
Least gelation concentration (%)	6.00±0.00^a	6.00±0.00^a	6.00±0.00^a	4.00±0.00^b	4.00±0.00^b	6.00±0.00^a	4.00±0.00^b	6.00±0.00^a	6.00±0.00^a	2.00±0.00^c

Values in the same column with different letters in superscript are significantly different at $p < 0.05$

UPB_{60} = Unripe Plantain Blanched at 60^{0}C for 5, 10 and 15 minutes

UPB_{80} = Unripe Plantain Blanched at 80^{0}C for 5, 10 and 15 minutes

UPB_{100} = Unripe Plantain Blanched at 100^{0}C for 5, 10 and 15 minutes

$UPUB_{CO}$ = Unripe Plantain Unblanched (Control)

Table 4.5: Sensory Properties of Reconstituted Plantain Flour (Amala)

Sample	Taste	Colour	Texture
UPB_{60-5}	6.7^{b}	$5.4^{b,c}$	6.2^{a}
UPB_{60-10}	8.7^{a}	$6.6^{a,b}$	7.5^{a}
UPB_{60-15}	8.5^{a}	7.6^{a}	7.4^{a}
UPB_{80-5}	4.6^{d}	4.8^{c}	3.2^{b}
UPB_{80-10}	3.6^{d}	8.0^{a}	4.4^{b}
UPB_{80-15}	6.7^{b}	$6.8^{a,b}$	7.3^{a}
UPB_{100-5}	3.4^{d}	7.8^{a}	3.8^{b}
UPB_{100-10}	$4.6^{c,d}$	7.5^{a}	7.6^{a}
UPB_{100-15}	$3.8^{c,d}$	4.2^{c}	4.4^{b}
$UPUB_{CO}$	$5.5^{b,c}$	$6.9^{a,b}$	7.7^{a}

Values in the same column with different letters in superscript are significantly different at $P < 0.05$

Table 4.6: Microbiological Quality of plantain flour blanched for 5, 10 and 15 minutes at 60, 80 and 100°C

Sample	UPB_{60}			UPB_{80}			UPB_{100}			$UPUB_{CO}$
	5	10	15	5	10	15	5	10	15	
TVC ($cfu/gx10^3$)	2.0	2.0	1.0	2.0	1.5	ND	1.4	1.0	ND	3.0
Coliform ($cfu/gx10^3$)	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Mould and yeast ($cfu/gx10^3$)	3.5	3.2	1.4	2.4	2.2	1.0	2.0	2.0	1.0	4.0

ND = Not Determined

UPB_{60} = Unripe Plantain Blanched at 60°C for 5, 10 and 15 minutes
UPB_{80} = Unripe Plantain Blanched at 80°C for 5, 10 and 15 minutes
UPB_{100} = Unripe Plantain Blanched at 100°C for 5, 10 and 15 minutes
$UPUB_{CO}$ = Unripe Plantain Unblanched (Control)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Subjecting plantain chip to different temperatures for different duration had varying effect on the nutritional composition and functional properties of unripe plantain flour. The results obtained showed that it is feasible to produce flour from unripe plantain with low moisture contents for prolonged shelf-life between six to twelve months. Results obtained also showed that the functional properties (bulk density, water and oil absorption) of the flours were affected by the different thermal treatments. This work has also shown the applicability of the flours as a function of their nutritional composition, different functional properties, sensory attributes and pasting properties. The oven dried flour has an advanatage of a pre-gelatinized or "pre-cooked" flour, which is an important characteristic of a ready to eat product.

The findings in this study also revealed that the Control samples (unblanched plantain) have some beneficial effect on the nutrients profiles, good pasting properties, short time and economy of the flour production, but has a disadvantage of producing a darker paste than the blanched samples. It also contains higher microbial load which lower its quality.

Samples blanched at 60^{0}C for 10 and 15 minutes were ultimately identified as the best plantain flour. This was observed from the proximate composition, pasting properties and the panelists preference. This could contribute to loss reduction in plantain fruits, improve nutritional intake and improved shelf life which will enable the food industry to store the product throughout the year.

5.2 Recommendation

Blanching of plantain at different temperature and time prior to dehydration will be a useful pretreatment in production of unripe plantain flour. The preferable treatment is blanching at 60°C for 10 to 15 minutes. The flour so produced could be used as a thickener in many food Industries, as emulsifying agent in colloidal food systems and supplementary foods, since low paste bulk (low viscosity in relations to solid concentrations) ensures higher intake of solids food for a given gruel volume consumed. There is need to encourage the use of whole plantain flour in baking and confectionaries from the point of view of their pasting properties.

The use of entire fingers of plantain after blanching could be a rapid approach in flour production with improved levels of nutrients, especially minerals, which are concentrated in the peel (Izonfuo and Omuaru, 1988).

People's main problem is the very high relative price of plantain compared to other staples like cassava, this is due to the post-harvest losses that is encountered in Nigeria, since plantain is seasonal, and no adequate storage facilities on ground to make it available round the year. Hence, post-harvest losses should be reduced i.e. provide good storage facilities, encourage good processing techniques, agronomic research extension services to help farmers in term of necessary information for the best cultivation method. Food scientists are also to encourage consumers and industries for the inclusion of plantain flour into the product recipes.

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APPENDIX 1

SENSORY EVALUATION QUESTIONAIRE

NAME..... DATE.....

INSTRUCTIONS:

You are provided with coded samples of plantain amala. Please evaluate them for the quality factors listed below using the scale provided .Rinse your mouth with water after each test.

Please keep in mind that you are the judge. An honest expression of your personal feeling will go a long way into helping me in the research

SCALE

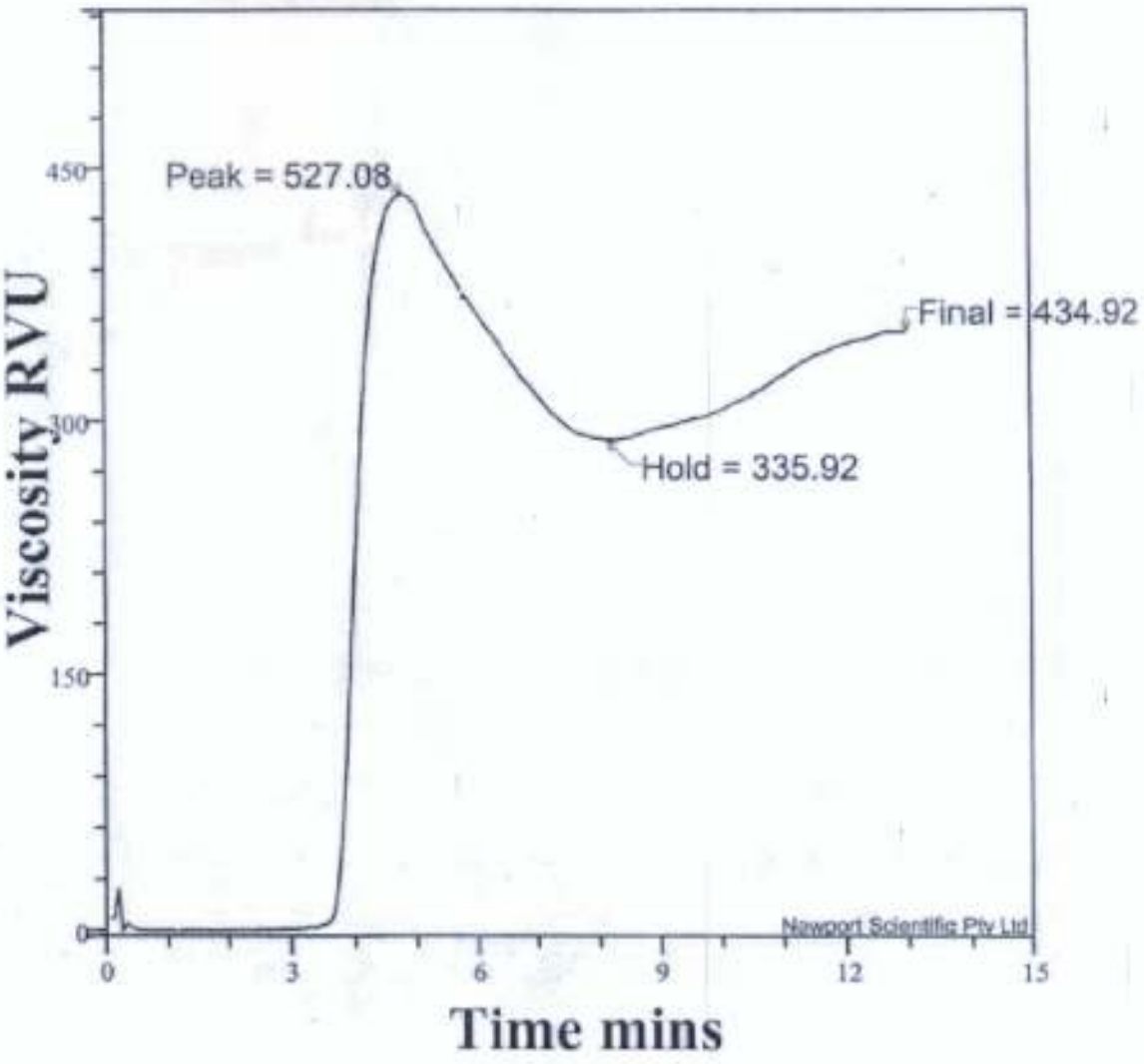
9	---Like extremely
8	---Like very much
7	---Like moderately
6	---Like slightly
5	---Neither Like nor dislike
4	---Dislike slightly
3	---Dislike moderately
2	---Dislike very much
1	---Dislike extremely

SAMPLE NO	TEXTURE	TASTE	COLOUR

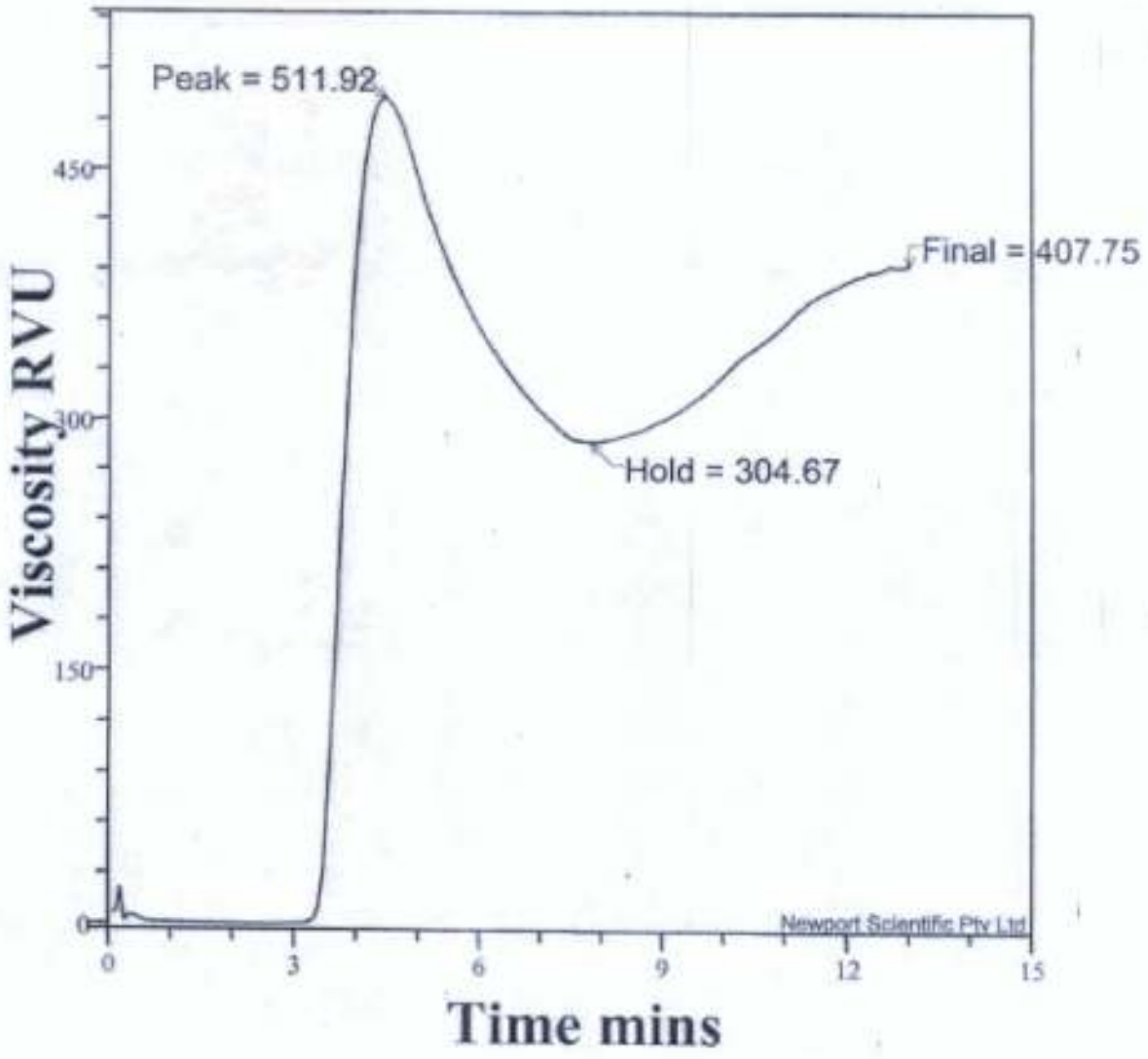
Please comments on any improvement you may desire in the products----------

---

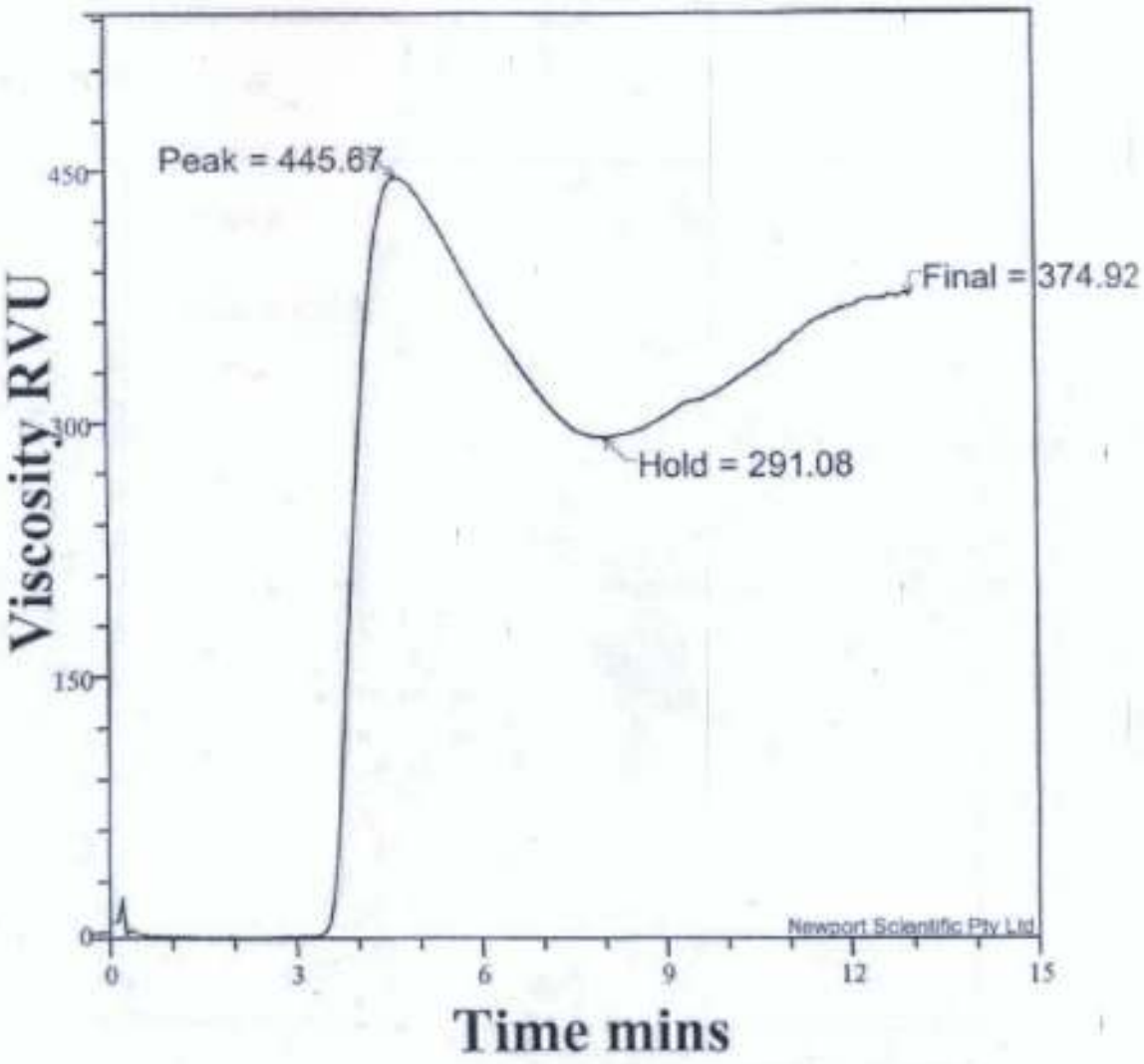
Thank you for your participation


Peak = 527.08
Final = 434.92
Hold = 335.92
Viscosity RVU
450
300
150
0
0
3
6
9
12
15
Time mins
Newport Scientific Pty Ltd

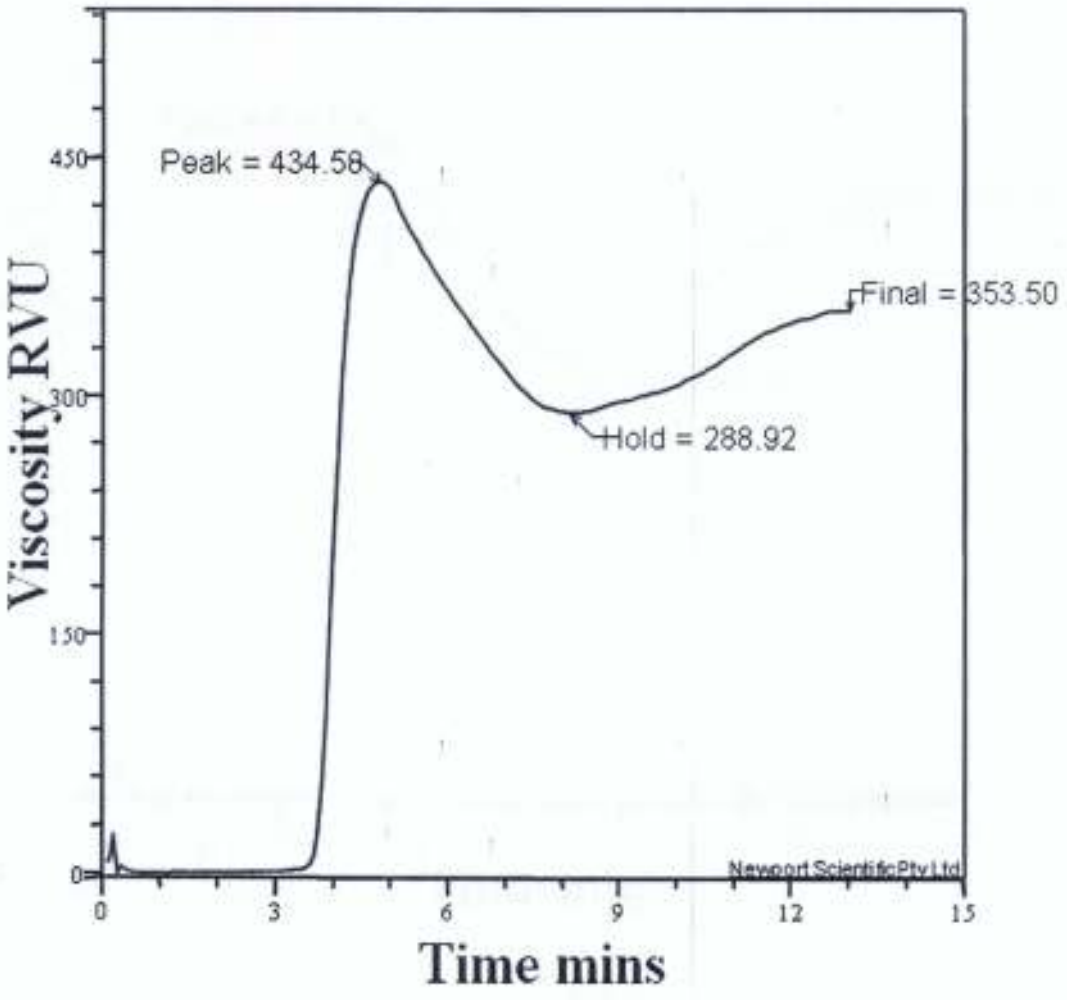
UPB_{60-5}



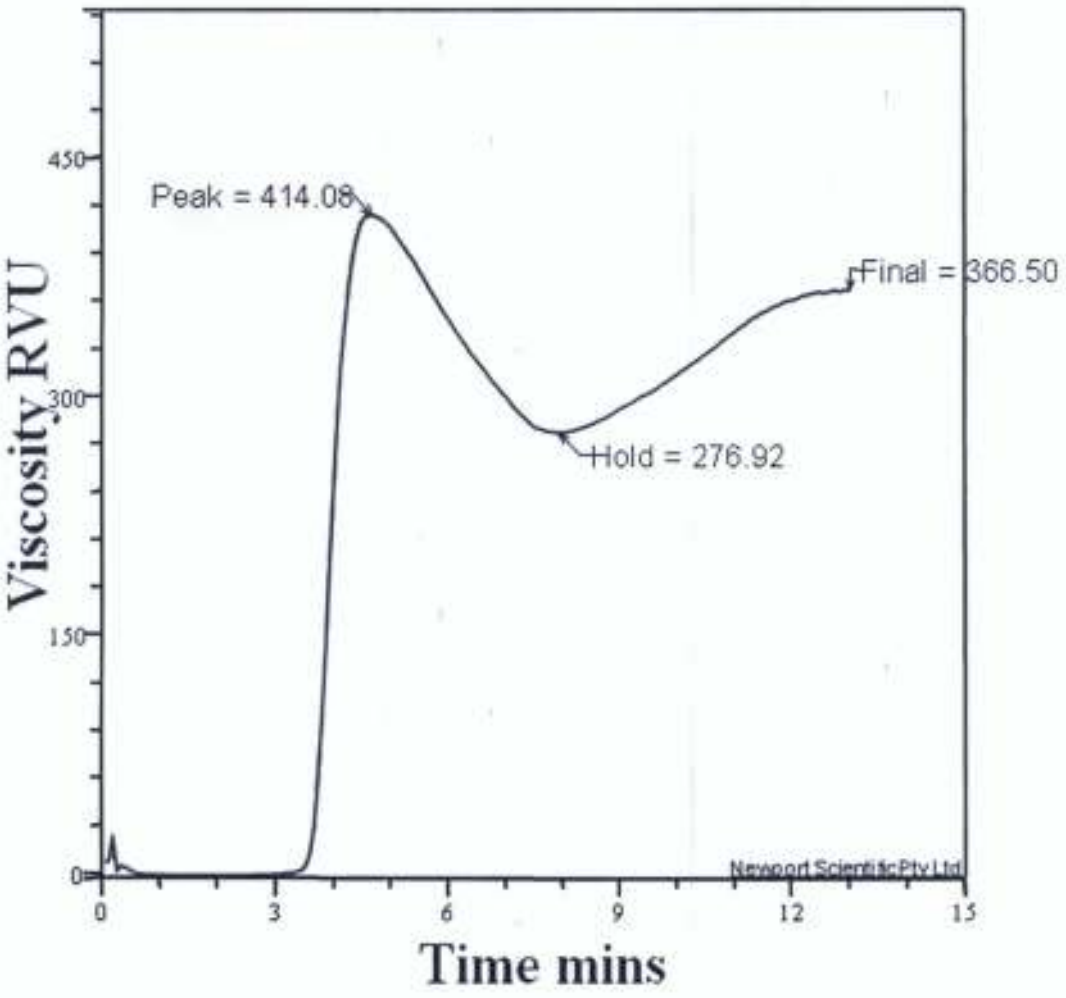
$UPB_{60\text{-}10}$


Peak = 445.67
Final = 374.92
Hold = 291.08
Viscosity RVU
Time mins
Newport Scientific Pty Ltd
450
300
150
0
0
3
6
9
12
15

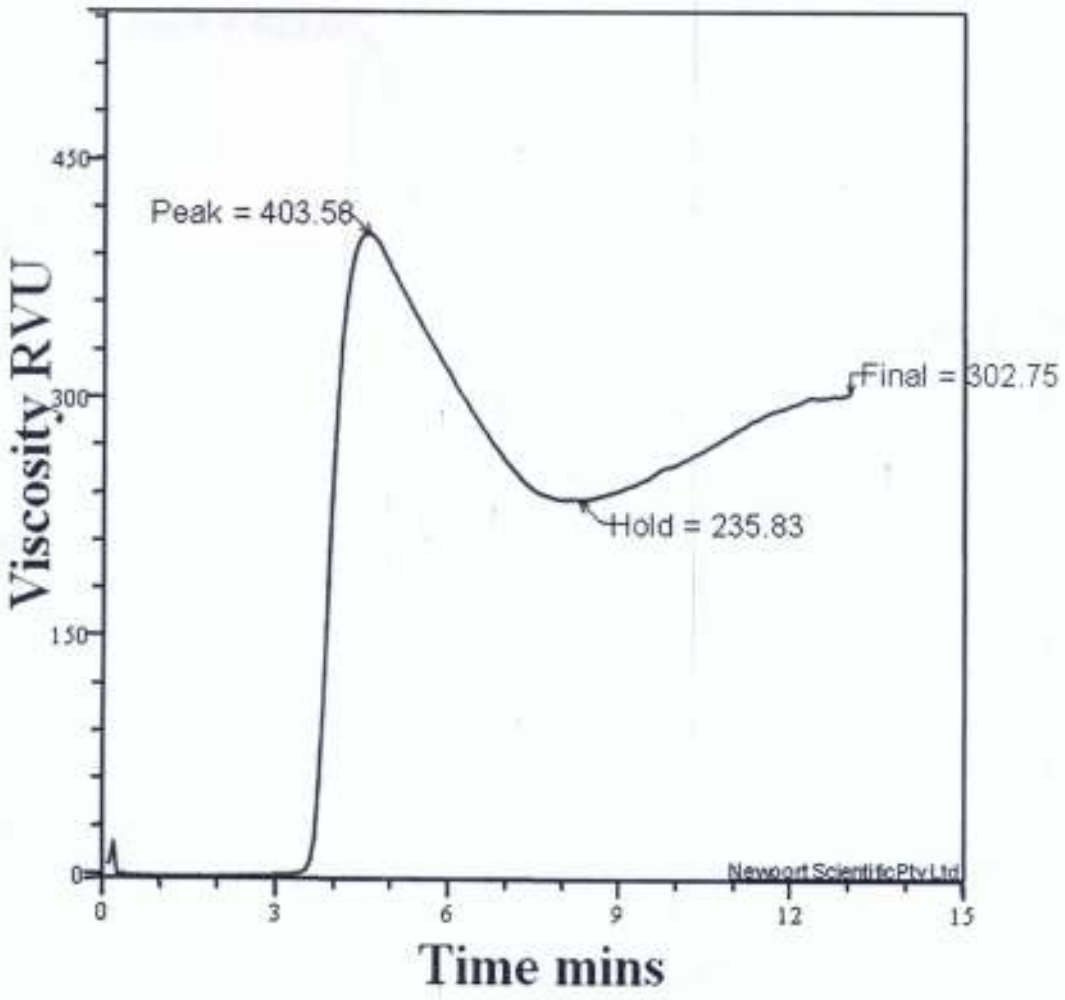
UPB_{60-15}


Peak = 434.58
Final = 353.50
Hold = 288.92
Viscosity RVU
Time mins
Newport Scientific Pty Ltd
450
300
150
0
0
3
6
9
12
15

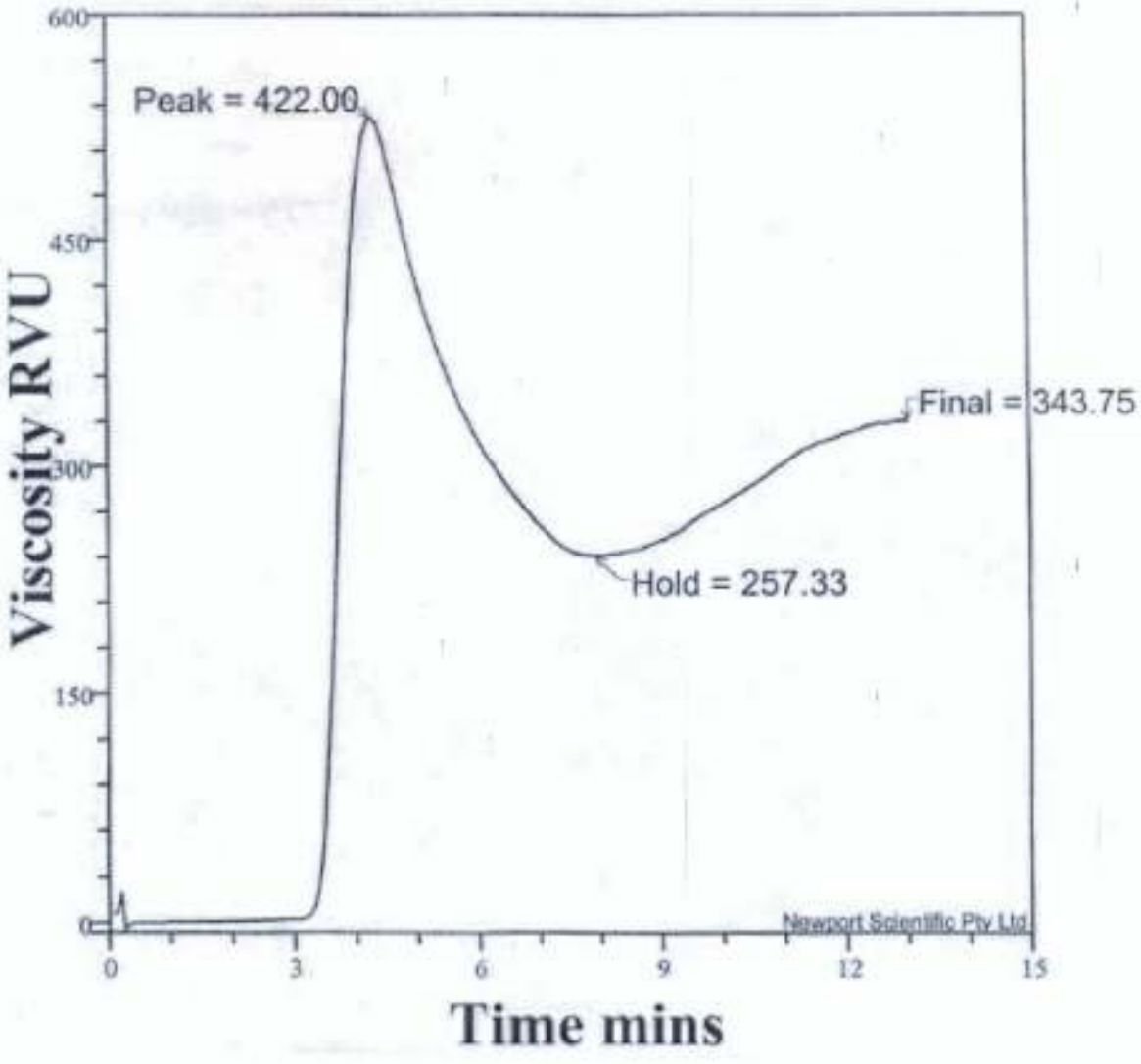
$UPB_{80\text{-}5}$



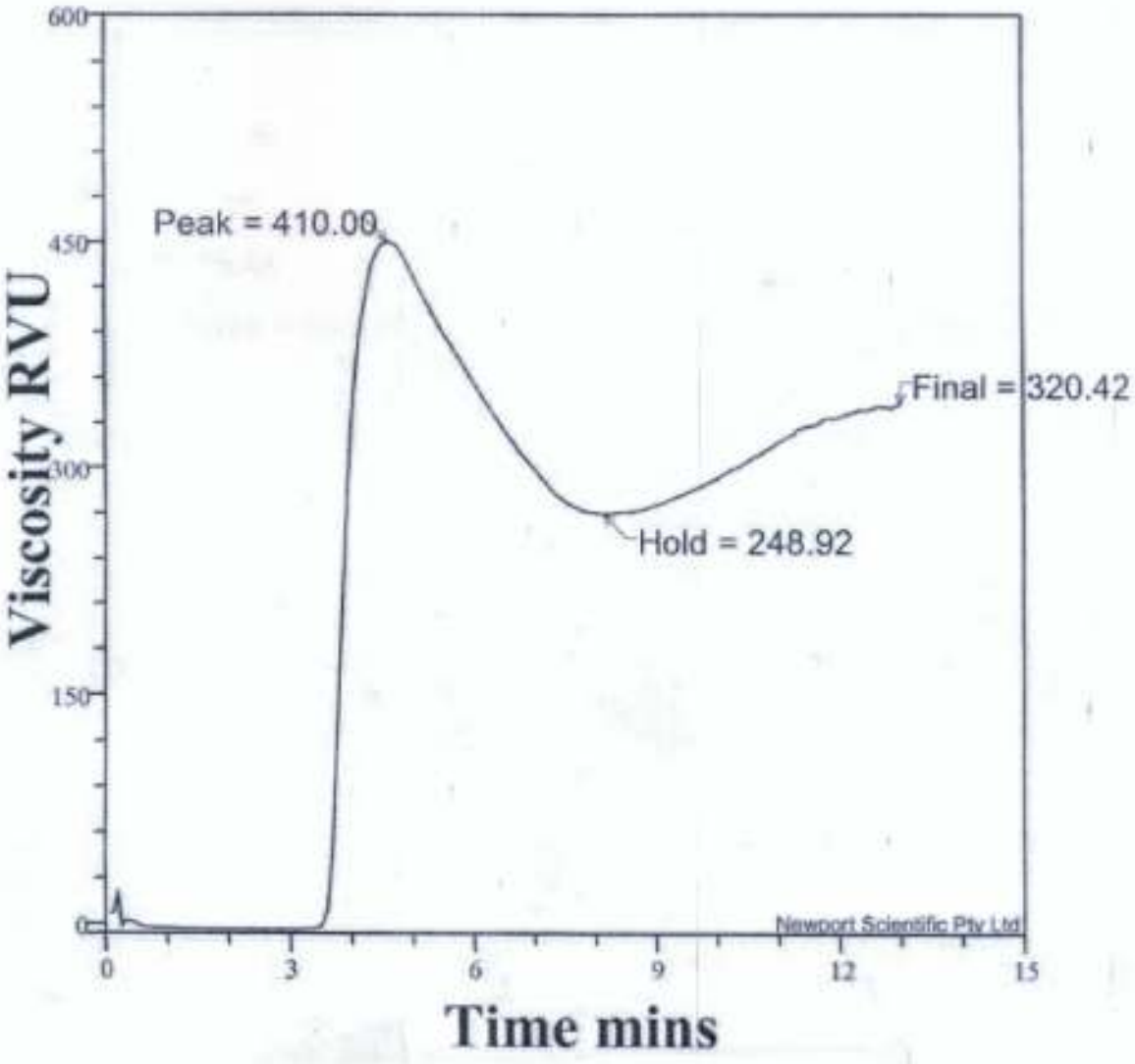
$UPB_{80\text{-}10}$



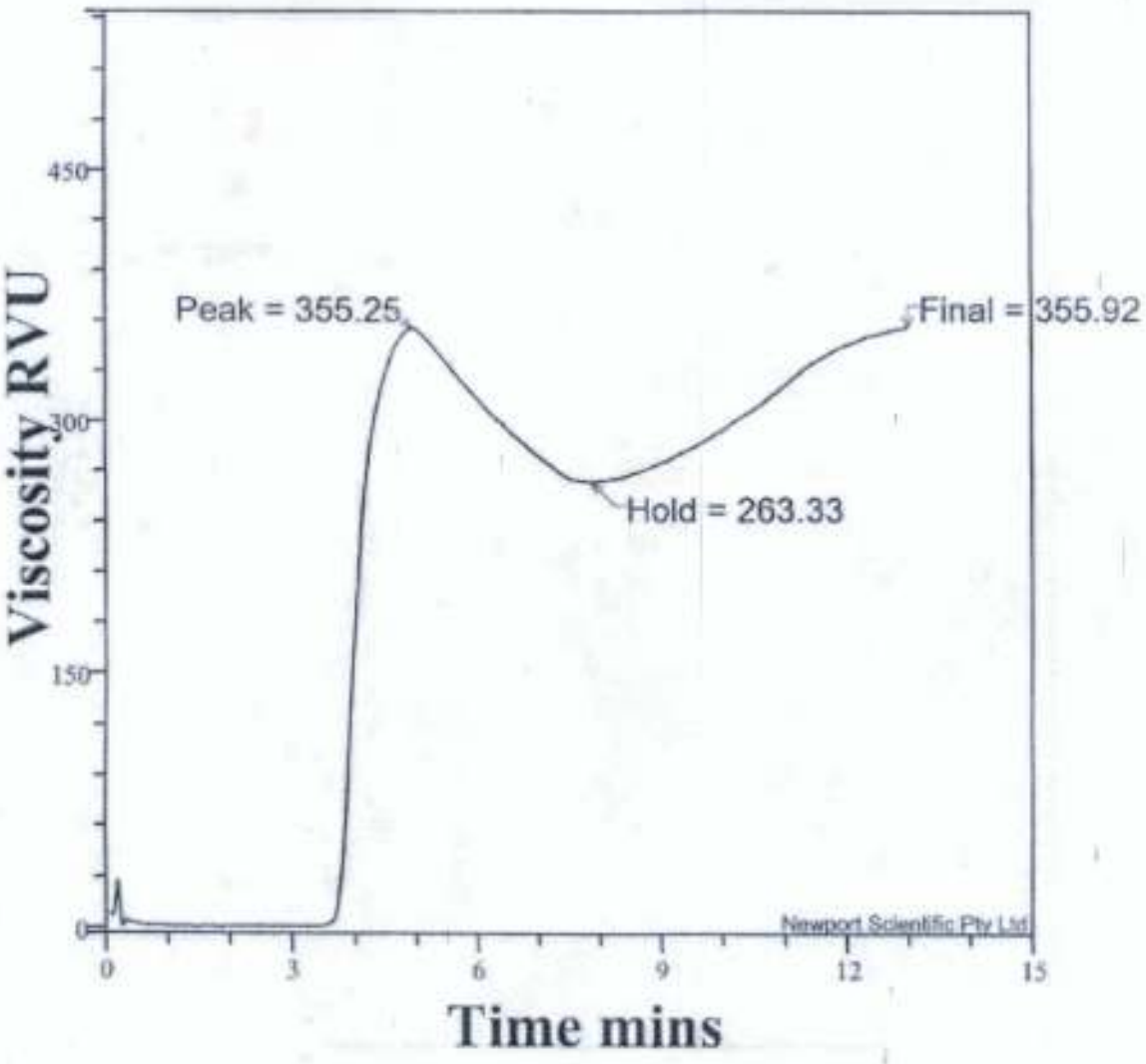
$UPB_{80\text{-}15}$



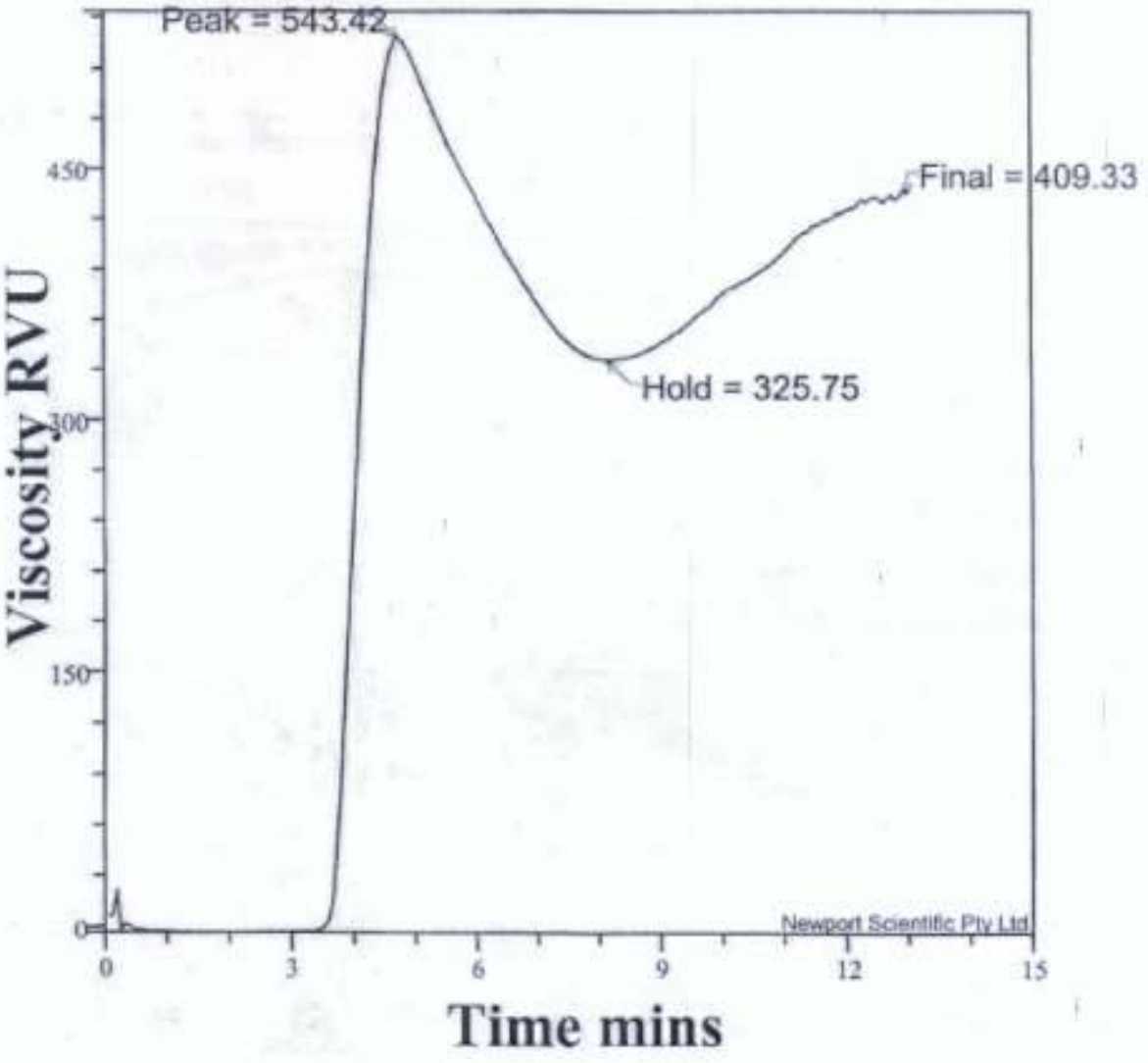
$UPB_{100\text{-}5}$


Peak = 410.00
Final = 320.42
Hold = 248.92
Viscosity RVU
Time mins
Newport Scientific Pty Ltd
600
450
300
150
0
0
3
6
9
12
15

UPB_{100-10}



$UPB_{100\text{-}15}$


Peak = 543.42
Final = 409.33
Hold = 325.75
Viscosity RVU
450
300
150
0
0
3
6
9
12
15
Time mins
Newport Scientific Pty Ltd

$UPUB_{CO}$

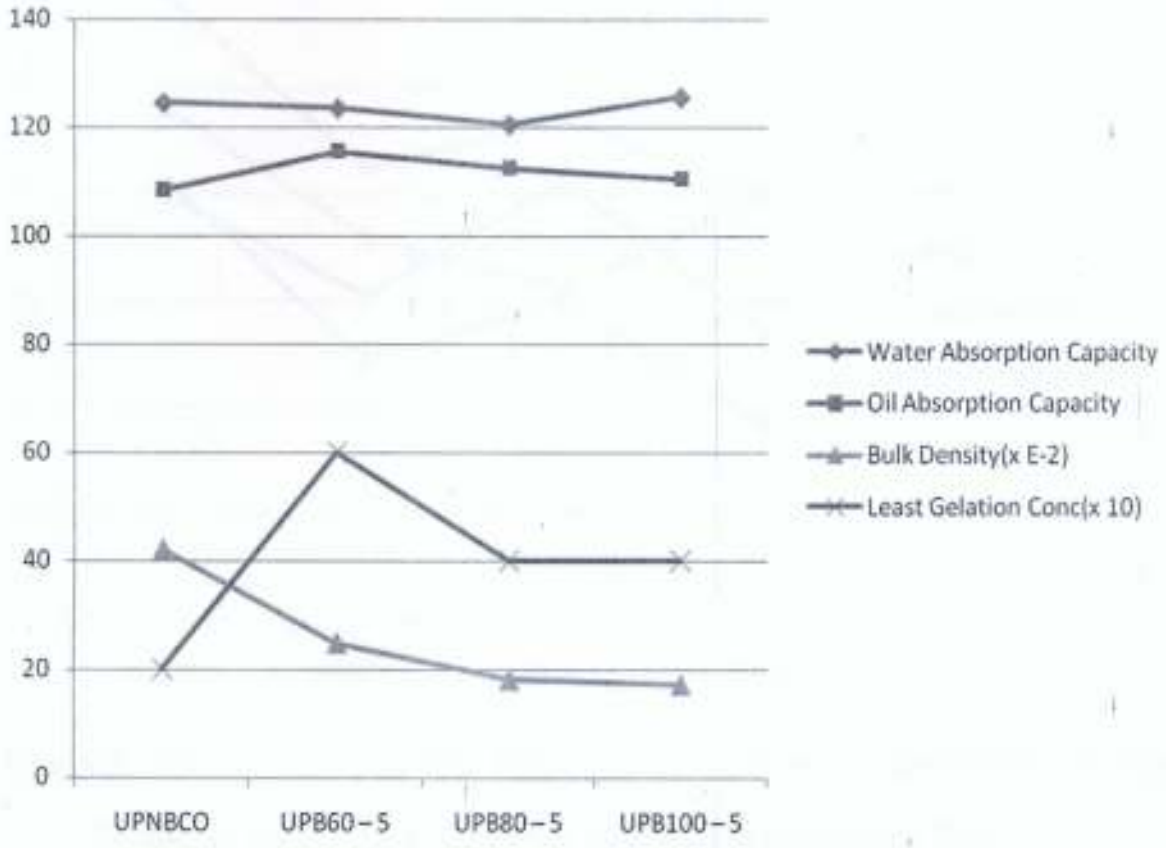


Figure 1: The effects of blanching temperature at 5 minutes on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

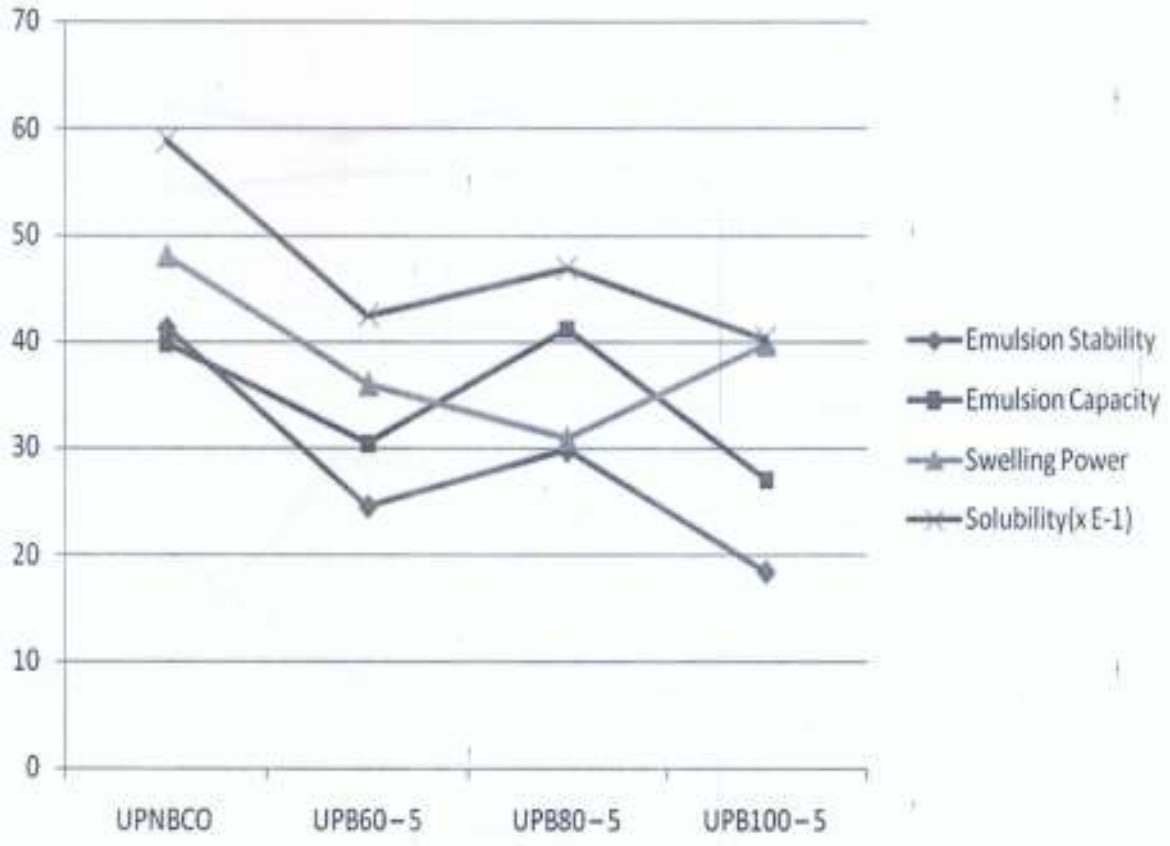


Figure 2: The effects of blanching temperature at 5 minutes on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

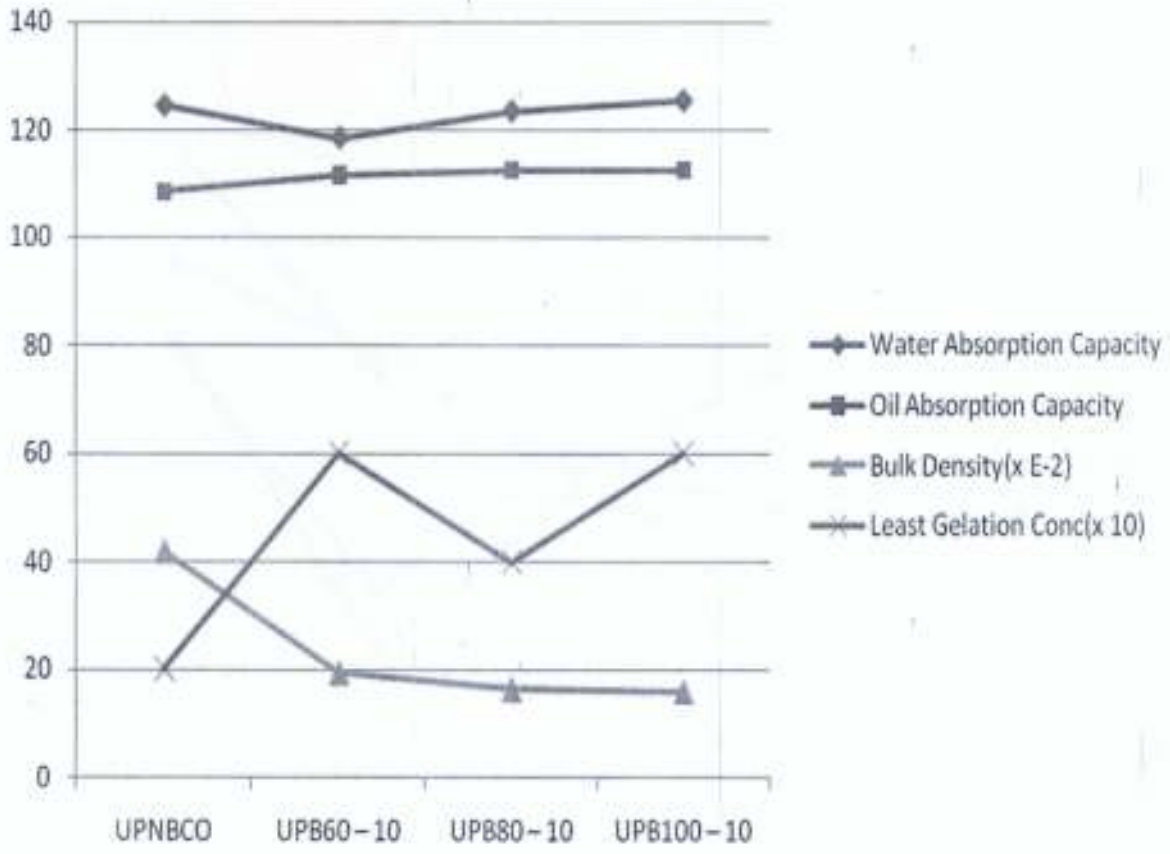


Figure 3: The effects of blanching temperature at 10 minutes on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

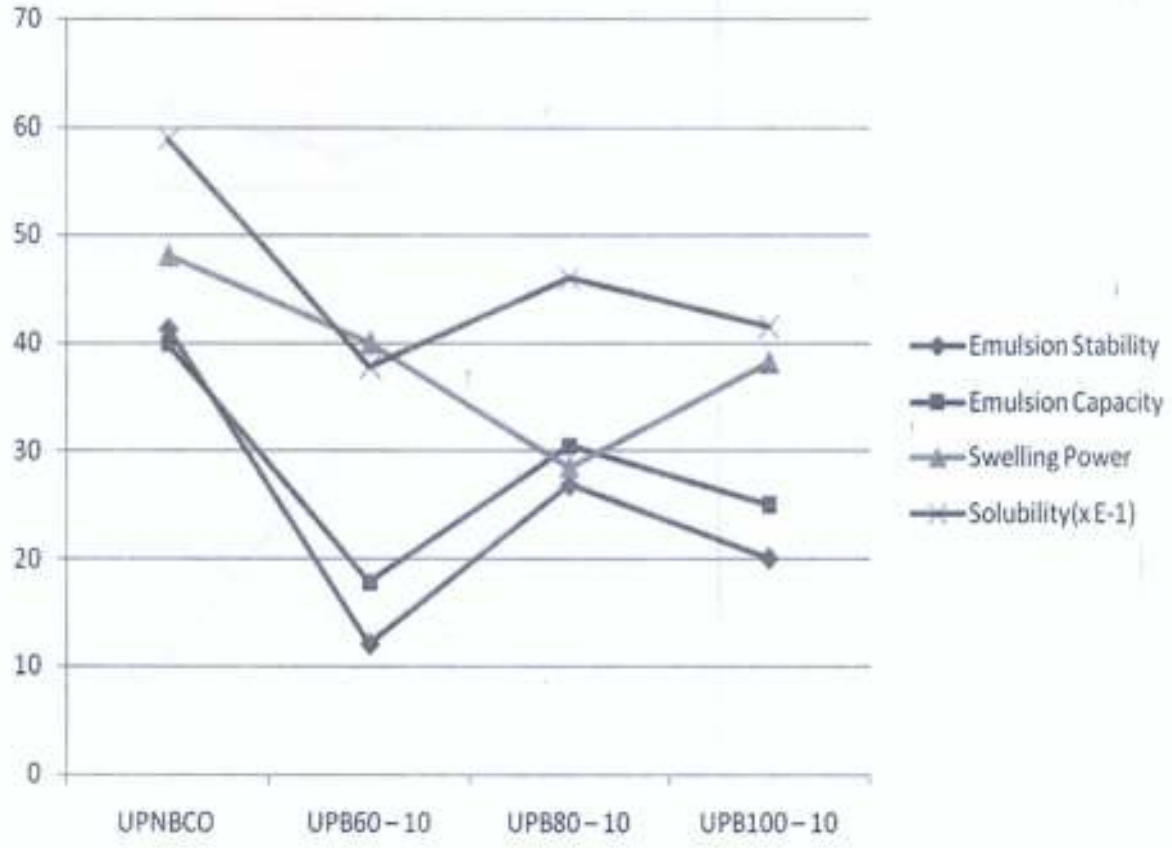


Figure 4: The effects of blanching temperature at 10 minutes on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

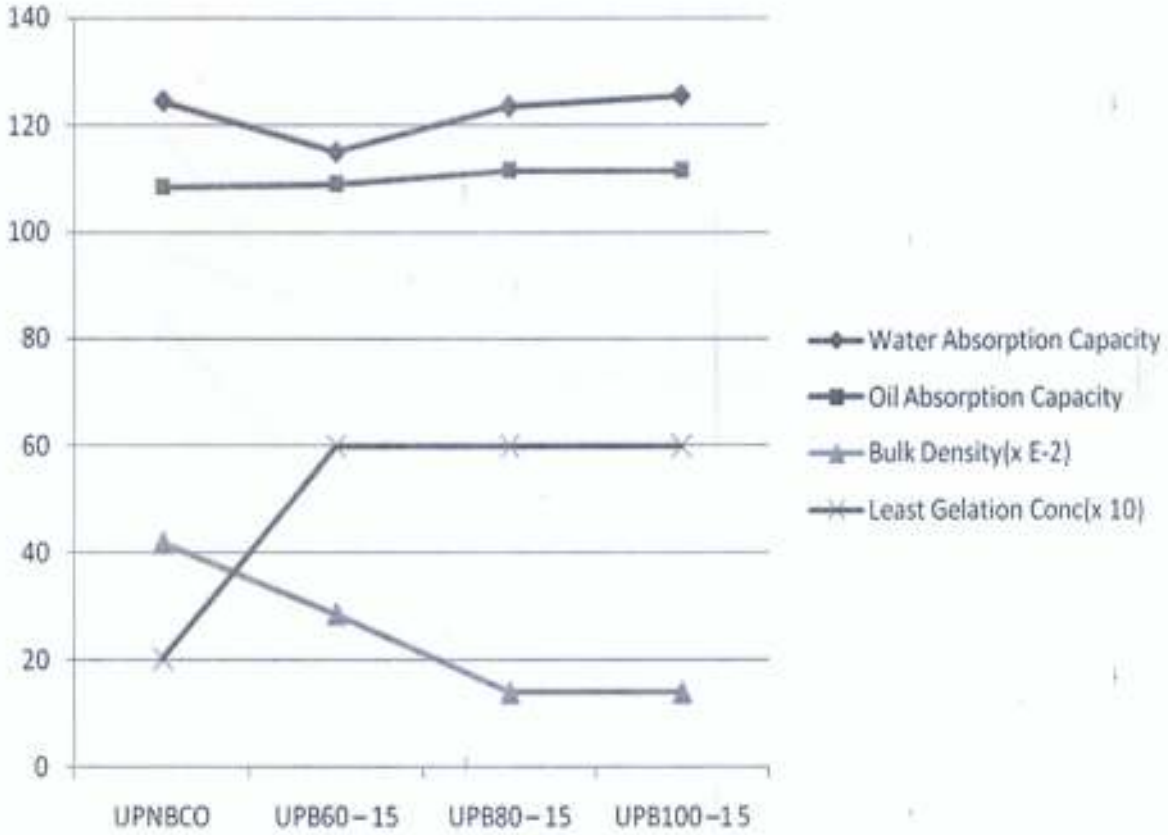


Figure 5: The effects of blanching temperature at 15 minutes on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

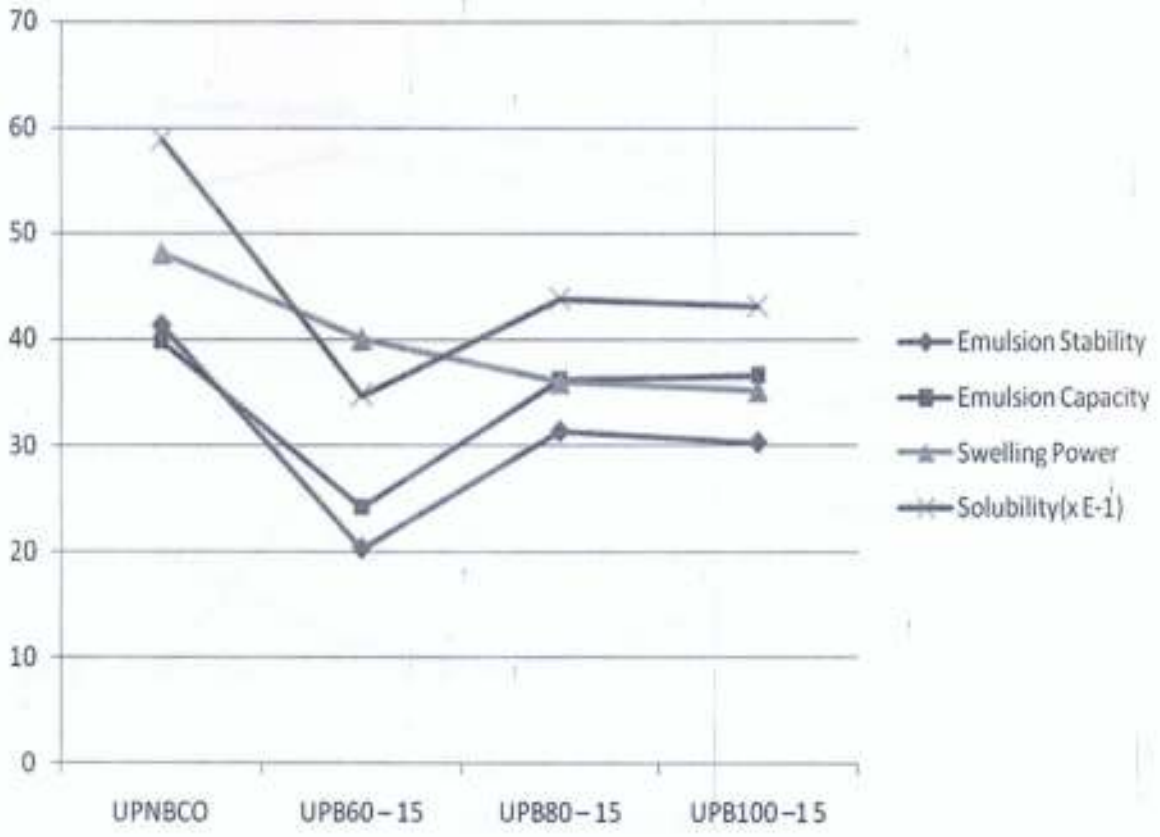


Figure 6: The effects of blanching temperature at 15 minutes on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

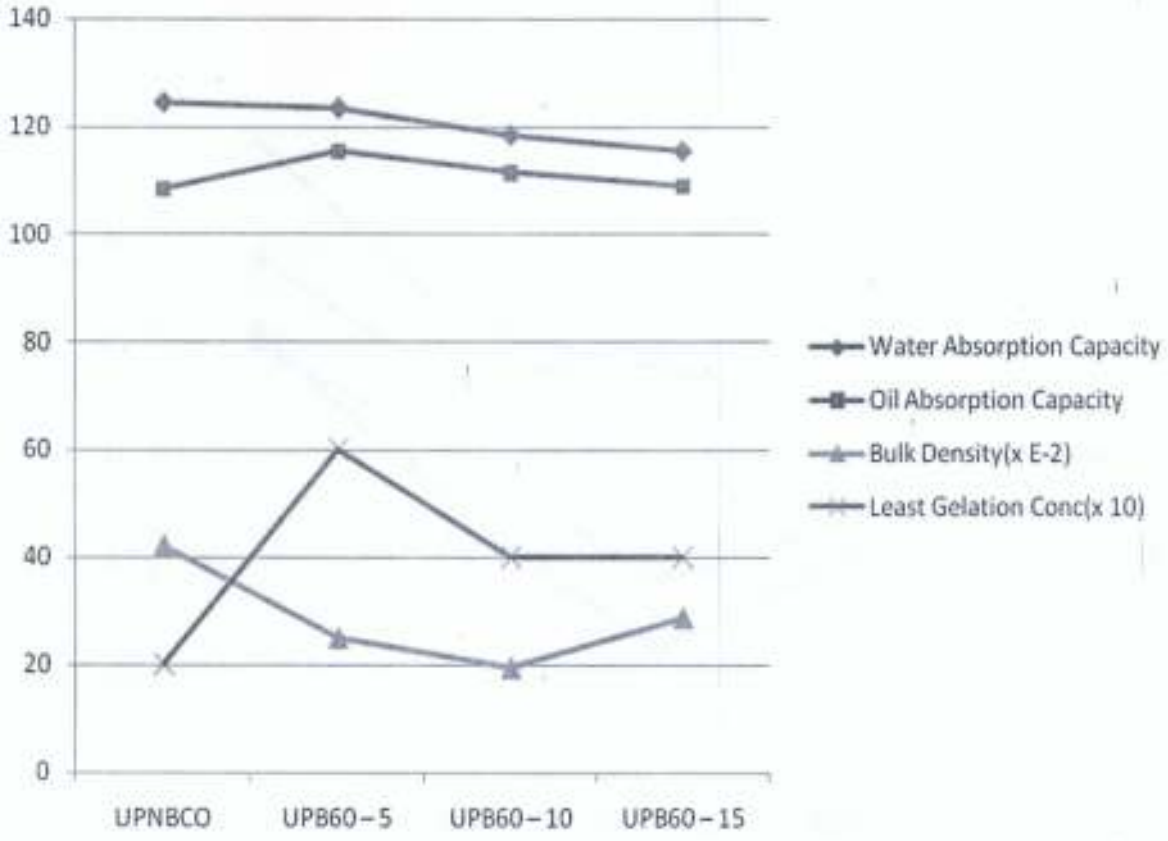


Figure 7: The effects of blanching time at 60°C on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

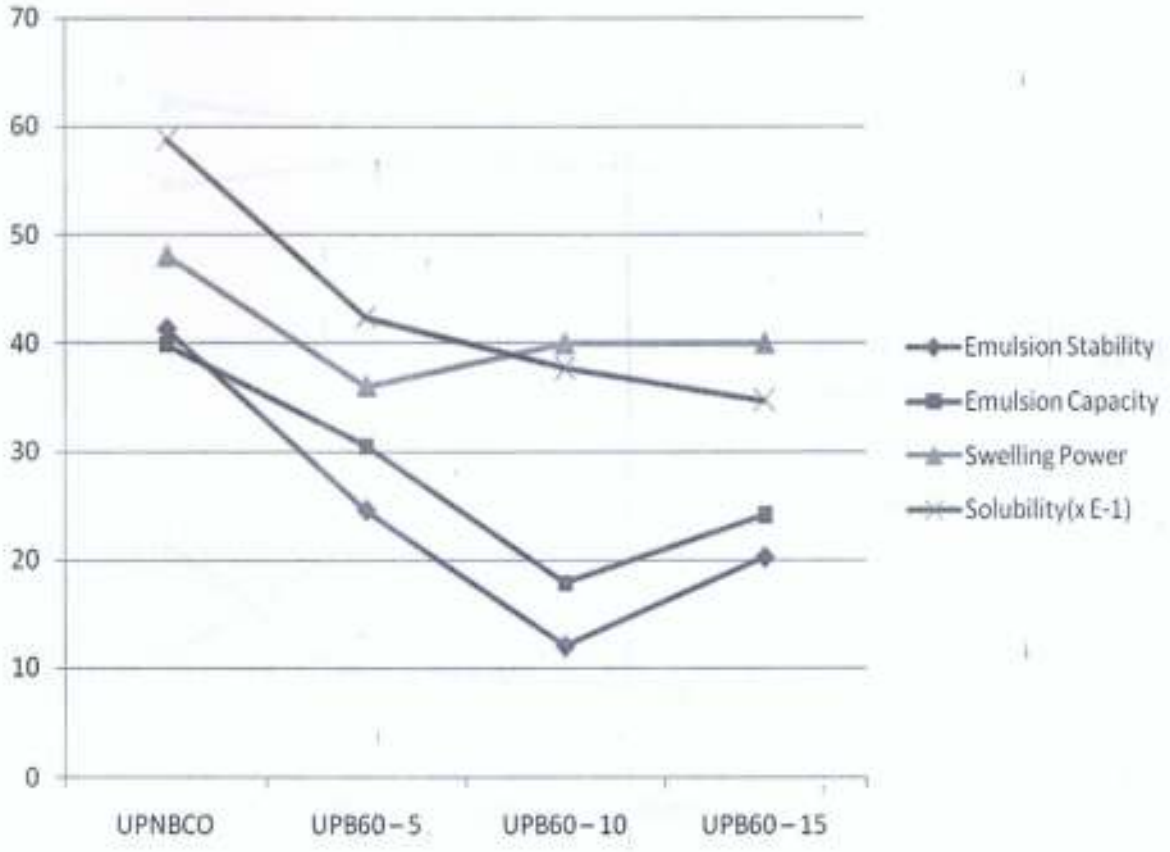


Figure 8: The effects of blanching time at 60°C on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

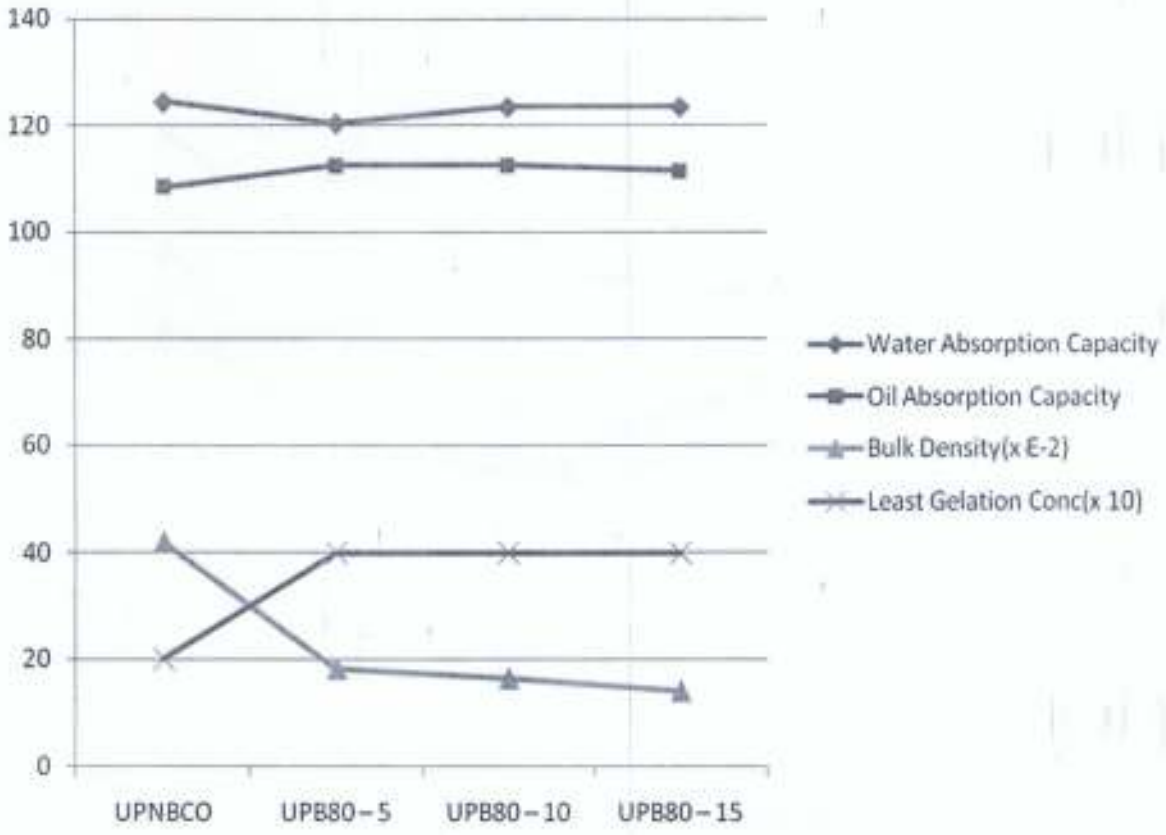


Figure 9: The effects of blanching time at 80°C on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

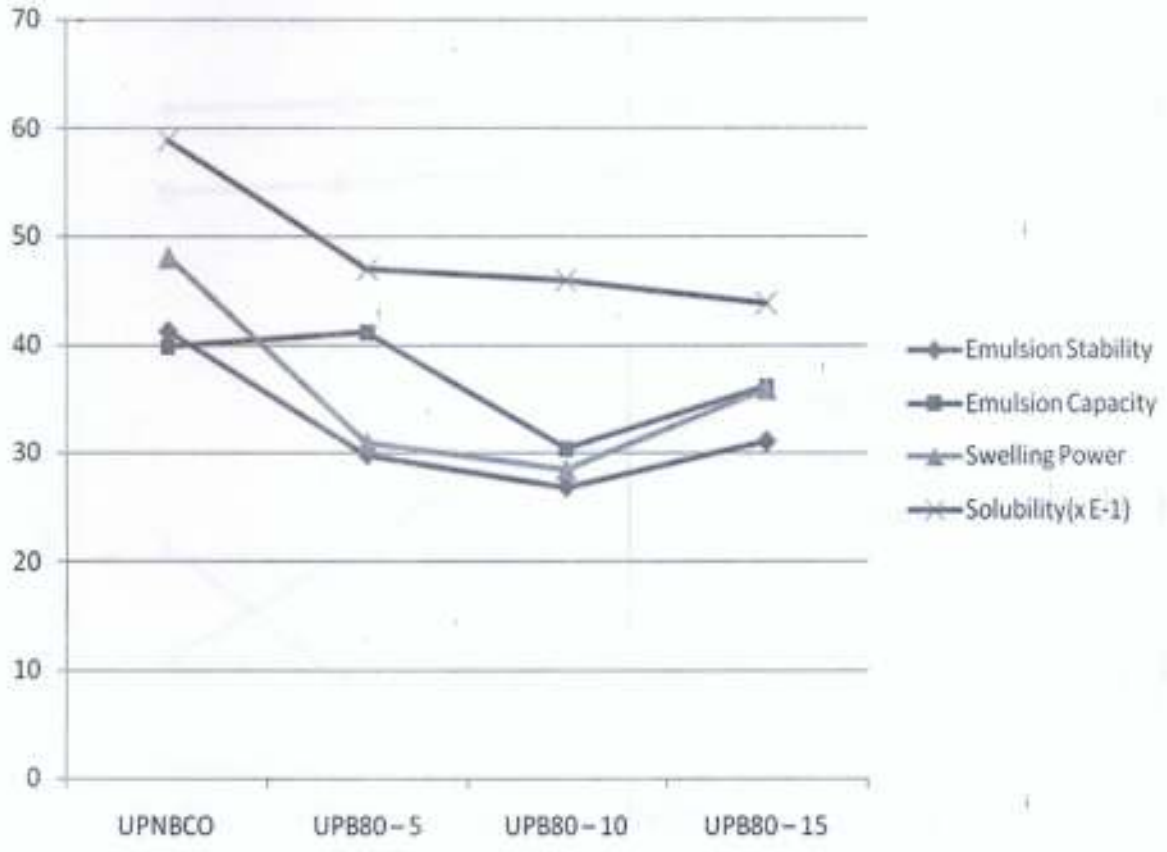


Figure 10: The effects of blanching time at 80°C on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

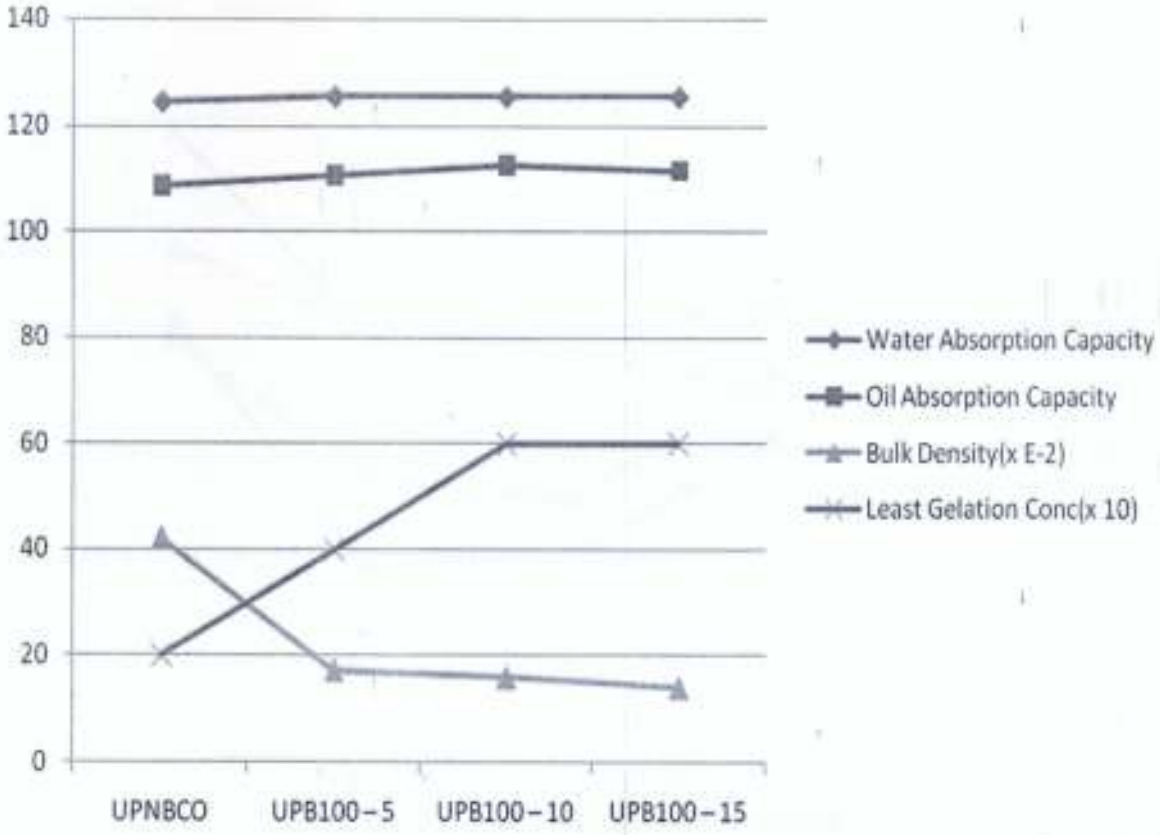


Figure 11: The effects of blanching time at 100°C on the Water Absorption Capacity, Oil Absorption Capacity, Bulk Density and Least Gelation Concentration of plantain flour.

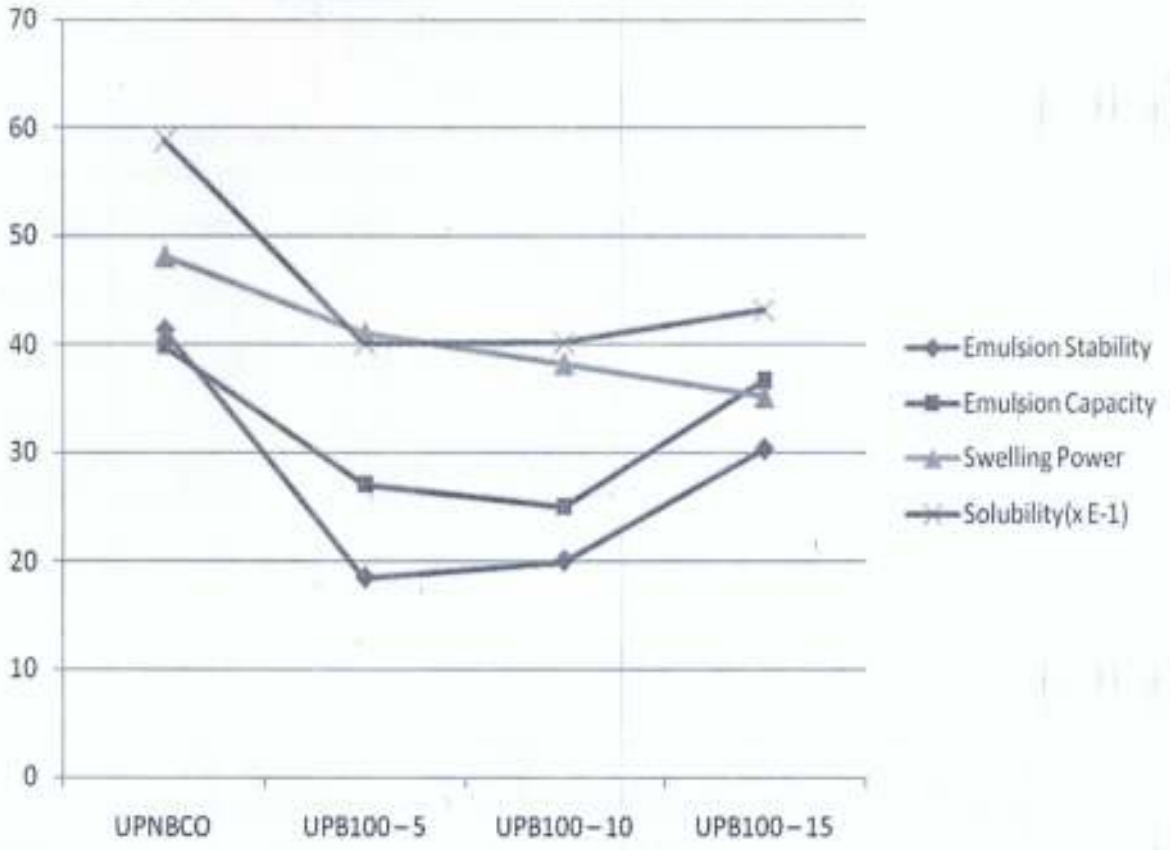


Figure 12: The effects of blanching time at 100°C on the Emulsion Stability, Emulsion Capacity, Swelling Power and Solubility of plantain flour.

Report

sample		zinc	copper	phosphorous
a	Mean	.0460	.0237	170.0000
	Std. Deviation	.00000	.00058	10.00000
b	Mean	.0437	.0207	120.0000
	Std. Deviation	.00252	.00153	20.00000
c	Mean	.0477	.0207	160.0000
	Std. Deviation	.00153	.00058	10.00000
d	Mean	.0520	.0307	155.0000
	Std. Deviation	.00100	.00153	5.00000
Total	Mean	.0473	.0239	151.2500
	Std. Deviation	.00345	.00438	22.37338

Oneway

[DataSet6]

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
calcium	Between Groups	115050.00	3	38350.000	25.355	.000
	Within Groups	12100.000	8	1512.500		
	Total	127150.00	11			
magnessium	Between Groups	48975.000	3	16325.000	435.333	.000
	Within Groups	300.000	8	37.500		
	Total	49275.000	11			
potassium	Between Groups	15225.000	3	5075.000	67.667	.000
	Within Groups	600.000	8	75.000		
	Total	15825.000	11			
sodium	Between Groups	8.738	3	2.913	616.425	.000
	Within Groups	.038	8	.005		
	Total	8.776	11			
manganese	Between Groups	.626	3	.209	49.808	.000
	Within Groups	.034	8	.004		
	Total	.660	11			
iron	Between Groups	.000	3	.000	8.000	.009
	Within Groups	.000	8	.000		
	Total	.000	11			
zinc	Between Groups	.000	3	.000	15.356	.001
	Within Groups	.000	8	.000		
	Total	.000	11			
copper	Between Groups	.000	3	.000	50.063	.000
	Within Groups	.000	8	.000		
	Total	.000	11			
phosphorous	Between Groups	4256.250	3	1418.750	9.080	.006
	Within Groups	1250.000	8	156.250		
	Total	5506.250	11			

Post Hoc Tests

Homogeneous Subsets

calcium

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
c	3	420.0000		
d	3		535.0000	
b	3		595.0000	
a	3			690.0000
Sig.		1.000	.095	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

magnessium

Duncan[a]

sample	N	Subset for alpha = .05			
		1	2	3	4
c	3	255.0000			
a	3		305.0000		
b	3			340.0000	
d	3				430.0000
Sig.		1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

potassium

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
c	3	110.0000		
b	3		150.0000	
a	3		160.0000	
d	3			210.0000
Sig.		1.000	.195	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

sodium

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
a	3	3.0067		
c	3	3.0067		
b	3		3.1867	
d	3			5.0300
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

manganese

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
b	3	1.7567		
c	3		2.0267	
a	3		2.0700	
d	3			2.4000
Sig.		1.000	.436	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

iron

Duncan[a]

sample	N	Subset for alpha = .05	
		1	2
b	3	.1200	
c	3		.1267
a	3		.1300
d	3		.1300
Sig.		1.000	.212

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

zinc

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
b	3	.0437		
a	3	.0460	.0460	
c	3		.0477	
d	3			.0520
Sig.		.103	.226	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

copper

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
b	3	.0207		
c	3	.0207		
a	3		.0237	
d	3			.0307
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

phosphorous

Duncan[a]

sample	N	Subset for alpha = .05	
		1	2
b	3	120.0000	
d	3		155.0000
c	3		160.0000
a	3		170.0000
Sig.		1.000	.196

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 3.000.

Means

[DataSet7]

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
calcium * sample	12	100.0%	0	.0%	12	100.0%
magnesium * sample	12	100.0%	0	.0%	12	100.0%
potasium * sample	12	100.0%	0	.0%	12	100.0%
sodium * sample	12	100.0%	0	.0%	12	100.0%
mangenese * sample	12	100.0%	0	.0%	12	100.0%
iron * sample	12	100.0%	0	.0%	12	100.0%
zinc * sample	12	100.0%	0	.0%	12	100.0%
copper * sample	12	100.0%	0	.0%	12	100.0%
phosphorus * sample	12	100.0%	0	.0%	12	100.0%

Report

sample		calcium	magnesium	potasium	sodium	mangenese	iron
a	Mean	585.0000	315.0000	155.0000	3.3700	1.9667	.1667
	Std. Deviation	5.00000	5.00000	5.00000	.06000	.04509	.03512
b	Mean	525.0000	320.0000	160.0000	3.3100	1.8167	.1267
	Std. Deviation	5.00000	10.00000	10.00000	.20000	.07506	.00577
C	Mean	675.0000	330.0000	120.0000	3.3867	1.7967	.1267
	Std. Deviation	5.00000	10.00000	10.00000	.07506	.02517	.00577
D	Mean	535.0000	430.0000	210.0000	5.0300	2.4000	.1300
	Std. Deviation	75.00000	.00000	.00000	.04000	.01000	.00000
Total	Mean	580.0000	348.7500	161.2500	3.7742	1.9950	.1375
	Std. Deviation	69.87001	49.73224	34.12044	.76395	.25667	.02340

Report

Mean

sample	taste	colour	texture
84.00	6.7000	5.4000	6.2000
205.00	3.8000	4.2000	4.4000
427.00	6.7000	6.8000	7.3000
429.00	4.6000	7.5000	7.6000
640.00	8.5000	7.6000	7.4000
641.00	3.4000	7.8000	3.8000
649.00	3.6000	8.0000	4.4000
861.00	4.6000	4.8000	3.2000
862.00	8.7000	6.6000	7.5000
863.00	5.5000	6.9000	7.7000
Total	5.6100	6.5600	5.9500

Oneway

[DataSet8]

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
taste	Between Groups	345.290	9	38.366	11.193	.000
	Within Groups	308.500	90	3.428		
	Total	653.790	99			
colour	Between Groups	157.640	9	17.516	6.040	.000
	Within Groups	261.000	90	2.900		
	Total	418.640	99			
texture	Between Groups	291.650	9	32.406	11.344	.000
	Within Groups	257.100	90	2.857		
	Total	548.750	99			

Post Hoc Tests

Homogeneous Subsets

taste

Duncan[a]

		Subset for alpha = .05			
sample	N	1	2	3	4
641.00	10	3.4000			
649.00	10	3.6000			
205.00	10	3.8000	3.8000		
429.00	10	4.6000	4.6000		
861.00	10	4.6000	4.6000		
863.00	10		5.5000	5.5000	
84.00	10			6.7000	
427.00	10			6.7000	
640.00	10				8.5000
862.00	10				8.7000
Sig.		.204	.063	.176	.810

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

colour

Duncan[a]

sample	N	Subset for alpha = .05		
		1	2	3
205.00	10	4.2000		
861.00	10	4.8000		
84.00	10	5.4000	5.4000	
862.00	10		6.6000	6.6000
427.00	10		6.8000	6.8000
863.00	10		6.9000	6.9000
429.00	10			7.5000
640.00	10			7.6000
641.00	10			7.8000
649.00	10			8.0000
Sig.		.141	.074	.117

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

texture

Duncan[a]

sample	N	Subset for alpha = .05	
		1	2
861.00	10	3.2000	
641.00	10	3.8000	
205.00	10	4.4000	
649.00	10	4.4000	
84.00	10		6.2000
427.00	10		7.3000
640.00	10		7.4000
862.00	10		7.5000
429.00	10		7.6000
863.00	10		7.7000
Sig.		.152	.085

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

Means

[DataSet9]

Case Processing Summary

	Cases					
	Included		Excluded		Total	
	N	Percent	N	Percent	N	Percent
wac * sample	12	100.0%	0	.0%	12	100.0%
oac * sample	12	100.0%	0	.0%	12	100.0%
bd * sample	12	100.0%	0	.0%	12	100.0%
es * sample	12	100.0%	0	.0%	12	100.0%
ec * sample	12	100.0%	0	.0%	12	100.0%
sw * sample	12	100.0%	0	.0%	12	100.0%
sol * sample	12	100.0%	0	.0%	12	100.0%
lgc * sample	12	100.0%	0	.0%	12	100.0%