UNIVERSITY OF CAPE COAST

ASSESSMENT OF THE IMPACT OF SOME PREHARVEST AND POSTHARVEST FACTORS ON PINEAPPLE JUICE QUALITY AND SAFETY

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BY

FRANCIS PADI LAMPTEY

Thesis submitted to the Department of Agricultural Engineering of School of Agriculture of the College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirements for the award of Master of Philosophy degree in Food and Post-Harvest Technology

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of the author research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: .... Date: ....

Francis Padi Lamptey

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised by the guidelines on supervision of thesis laid down by the University of Cape Coast.

Principal Supervisor's Signature: .... Date: ....

Name: Dr. Ernest Teye

Co-Supervisor's Signature: .... Date: ....

Name: Prof. Ernest Ekow Abano

ABSTRACT

Pre- and postharvest factors play an important role in pineapple juice quality. In this study, the impact of maturity stage (unmatured, matured and overmatured), time of harvest (morning, afternoon and evening) and storage temperature (ambient and refrigeration) of fruits on pineapple juice quality were assessed using a completely randomized design with three replications. There was a significant increase in TSS (from 14 ^{o}B to 16 ^{o}B), total antioxidant content (139.25mg/kg - 220.95 mg/kg), total phenol content (from 50.02 mg/l to 63.53mg/l) and total flavonoids (from 7.68 mg/l to 9.61 mg/l) for overmatured fruits harvested in the morning and stored in the ambient before processing into juice. There was a significant difference between the interactions of maturity stage, time of harvest and storage temperature of fruits on the nutritional composition of pineapple juice. Sensory attributes were also evaluated on the maturity stage, harvest time and storage condition. For maturity stage, juice extracted from the overmatured pineapple fruits had higher overall acceptability compared to the others. Harvesting pineapple in the morning followed by ambient storage condition, resulted in pineapple juice with higher colour, taste and after taste score. Among the treatments, juice from overmatured pineapple fruit harvested in the morning and stored in ambient condition was considered to be more appealing to the panelists. The total plate count of the juice produced from all treatments ranged from 0 to 4.164 log CFU/ml, while yeast and mould count ranged from 1.903 to 4.227 log CFU/ml which were all below the microbial limit for juice. From this study juice extracted from overmatured fruits harvested in the morning has rich nutrient with good consumer preference.

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DEDICATION

Dedicated to my lovely sister, Francisca Padikie Lamptey and my dear parents; Mr. Thomas Lamptey and Mrs. Vida Tetteh.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
CFU	Colony-forming units
FAO	Food and Agriculture Organization of the United Nations
HCL	Hydrochloric acid
SC	Smooth Cayenne
SL	Sugarloaf
TAA	Total Titratable Acidity
TDS	Total Dissolved Solids
TSS	Total Soluble Solids
UCC	University of Cape Coast
TPC	Total Phenolic Content
Vit C	Vitamin C

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Pineapple is a significant commercial fruit and belongs to the family of Bromeliaceae. Pineapple fruits are usually eaten fresh or juiced. Pineapple fruits are an excellent source of vitamins and minerals and provide the pleasure of eating with varieties of color, flavor and texture (Othman, 2011). Among the world tropical fruits, pineapple is ranked as the third most important (Van de Poel *et al*., 2009). In 2017, global production reached 27 million tons, with Costa Rica as the world's leading producer with 11.2% of global output followed by the Philippines (9.7%), Brazil (8.2%), Thailand (7.7%) and India (6.8%) (FAOSTAT, 2017). According to this FAOSTAT, the total production of Africa's pineapple was approximately 5.44 million tons in 2017, of which Ghana contributed approximately 677 thousand tons, approximately 12.4% of total production in Africa.

According to the Ministry of Food and Agriculture, (MoFA, 2002), pineapple-farming surveys have shown that most of Ghana's appropriate pineapple-farming sites are located in the southern portion of the nation, namely, Greater Accra, Central and Eastern region (Asare, 2012a). These areas have the ideal pineapple cultivation climate and environmental conditions. Pineapple is also grown in the Brong-Ahafo, Ashanti, Volta, and Western region (Asare, 2012). Pineapples are grown both on large- and small-scale. The bulk of pineapples from large scale farms are mainly for processed and fresh export markets, with only a small proportion going to local markets. Small scale growers, on the other hand, produce mainly for domestic local fresh markets. As food globalization progresses, the amount of globally traded agricultural products has increased. Although pineapple fruits are processed into a broad spectrum of products including concentrates of pineapple juice, pineapple pulp, dried pineapple and pasteurized pineapple juice, they are mostly consumed in fresh form in Ghana and many other developing countries (Sudheer and Indira, 2007).

Pineapple fruits are perishable and require coordination from activities such as growing, storage, processing and retailing, in order to ensure quality and reduce postharvest losses. Several physicochemical changes after harvest and microbial load lead to deterioration of pineapple after harvest. Environmental post-harvest conditions, particularly temperature, have a major impact on fruit quality; visual, compositional, and eating. Temperature is the component of the post-harvest environment which has the greatest impact on fresh fruit and vegetable quality. Harvesting pineapple fruits early in the morning would safeguard against the sun according to Ahmad and Siddiqui (2015). Harvesting pineapple fruits early in the morning or late in the afternoon or at night, could decrease the heat load on harvested fruits during precooling.

A significant determinant of many quality traits is the maturity stage of pineapple fruit at harvest (Shamsudin *et al.,* 2007). Pineapple, which is a non-climacteric fruit, can be harvested during maturity at distinct phases. At the point where it's mature green, half mature, or red mature, it can be collected. Each phase of pineapple fruit harvest has its postharvest attribute and consequently, the fruit can show important quality variability. Variables of maturity; firmness, skin color, starch breakdown, acid, sugars, ethylene, and carbon dioxide biosynthesis are also helpful indicators for identifying quality characteristics of fruit (Watkins *et al.*, 2005). Adikaram and Abayasekara (2012) revealed that when the peel color turns from green to yellow at the base of the fruit, then, the pineapple maturation stage is evident. Generally, the fruit becomes ready to harvest when 30–50 percent of the eyes turn yellow from the base. Pineapple harvesting maturity may also differ based on the intent and destination of the market. For distant markets, it is best to harvest slightly early when it is 10-20% yellow or even 100% green but at a mature phase, just before these striking modifications in color start. The fruits are metabolically active and undergo processes of maturation and senescence, which may need to be controlled in order to prolong the postharvest quality.

Juicing pineapple is assumed to be one of the important ways to reduce the postharvest loss that the pineapple fruit may undergo. However, the short life of fresh pineapple juice tends to impede the growth of the domestic juice industry, and this is thought to be mainly influenced by the growth of microorganisms (Shamsudin *et al.*, 2013).

In the course of storage of pineapple juice, there is an inevitable decline in quality value as the physicochemical properties are sensitive to some storage and environmental conditions (Olorunsogo and Adgidzi, 2013). According to studies by Thompson *et al.*, (2018), Queen pineapples stored at 2 or 4 °C developed a white, watery pulp while the fruit stored at higher temperatures developed browning within the fruit. Consumers may reject juice when stored at 3 and 8 °C for more than two weeks, whereas at room temperature of 20 °C the fruit juice could be kept for only about three days, and customers could still prefer it. Minimal studies have been conducted to understand the effects of time of harvest, maturity stage, and storage temperature on pineapple juice quality and safety.

1.2 Statement of the Problem

In many pineapple growing areas, the pineapple fruits are mostly cultivated with little or no idea of the effect of time of harvest, maturity stage, and variety on the quality of pineapple fruit and its effects on juice. The inability of pineapple producers to relate the importance of these factors may lead to the many fruit wastages in the pineapple sector.

The pineapple industry usually experiences peak harvesting from October to December, and from February to April/May in Ghana (Kleemann, 2016). Within those periods, the demand from the European market for pineapple is very high. Although the demand is high, producers are sometimes not able to provide quality pineapple fruit to the market. These render producers with no option than making a loss in production.

In addition, pineapple fruit juice production in Ghana is beset with numerous problems including seasonality of production and insufficient fruit production. The use of different pineapple varieties brings about variability in the juice produced from the pineapples. Pineapple juice producers are forced to use different varieties depending on when preferred varieties are unavailable.

Furthermore, with pineapple being a non-climacteric fruit, harvest time and storage temperature may have a detrimental effect on the quality of fruit juice. The need for pineapple producers and processors in Ghana to adapt to the flexibility of frequent changes in the variety of pineapple fruit is a dilemma (Gatune *et al*., 2013). The local pineapple growers are not able to adapt to the quick switch from one variety to another due to low technological adoption and high initial capital required to start the growth of a new variety. There is, therefore, the need for pineapple juice processors to stick to one variety with the best nutritional, physicochemical, and sensory properties.

1.3 Significance of the Study

The demand for freshly squeezed high quality juice is increasingly becoming a necessity because of safety awareness (Varela-Santos *et al*., 2012). The quality of processed pineapple fruit is a function of physicochemical characteristics such as pH, acidity, fiber, moisture, TSS and other chemical constituents as well as sensory properties (Buzrul *et al*., 2008; Jordan *et al*., 2001).

Also, if not properly processed and stored, fruit products are extremely susceptible to microbial decay (Osuntogun and Aboaba, 2004). Most lactic acid bacteria, coliforms, yeasts, and moulds cause spoilage because they can ferment carbohydrates and generate undesirable modifications such as the manufacturing of proteins, alcohols, and diacetyl, which adversely affect the chemical and organoleptic characteristics of foods (Lima *et al*., 2009). Such changes make the products unable to meet export market standards and may cause food-related health problems. While some studies have concentrated on the safety of pineapple juice (Bagde and Tumane, 2011), as well as its dietary (Al-Jedah and Robinson, 2002) and sensorial quality (Wen and Wrolstad, 2002), the impact of maturity level, range, harvesting time and storage time on the quality features of pineapple juice in Ghana has not yet been explored. The findings from this study will provide guidance on how to minimize the degradation of quality in the nutritional composition so that consumers can still benefit from their consumption to produce better shelf-stable marketable pineapple juice.

1.4 Objective of the Study

1.4.1 General Objective

The general objective was to assess the impact of maturity stage, time of harvest, and storage temperature of pineapple fruits on pineapple juice quality and microbial safety.

1.4.2 Specific Objectives

To assess the impact of maturity stage, time of harvest and storage condition of fruits on:

1. Physicochemical properties of pineapple juice.
2. Sensory properties of pineapples juice.
3. The microbial safety of pineapple juice.

1.5 Limitations

The pineapple fruits used for the study were harvested on different days. Moreover, since the experiment involved different phases, executed at different times, the raw materials were acquired and processed at different dates.

1.6 Delimitations

The study was conducted mainly in Cape Coast, Central Region of Ghana. The analytical determinations were done at the University of Cape Coast Chemistry Laboratory and Department of Laboratory Technology.

CHAPTER TWO

LITERATURE REVIEW

Pineapple is referred as *Ananas comosus*, and it is perennial herbaceous. The size of the pineapple plant is about 1–2 m in height and width. Its leaves are spirally arranged and flowers produce edible fruit at the ends of the terminal. The stem's center is about 25 to 50 cm long. There are between 60 and 80 leaves in a mature pineapple plant. Many variables, including rainfall, soil type, nutrient requirements, drainage, and temperature, contribute to the actual production of pineapple.

2.1 Varieties of Pineapples

Globally, there are around 30 pineapple cultivars growing in different environmental variables in tropical regions, but for commercial ease, these different cultivars are classified into four groups, called "Red Spanish", "Queen", "Sugarloaf" and "Smooth Cayenne" (Morton and Dowling, 1987). A new variety, called' Del Monte Gold', also known as MD-2 (Crane, 2013) has been bred more lately.

2.1.1 Sugar Loaf

This variety is closely related to 'Abacaxi,' which is also known as 'White Sugarloaf or 'Kona Sugar Loaf.' It is the third variety in addition to MD2, and smooth cayenne, which is cultivated on a large scale in Ghana. From 2.3-2.7 kg, the fruit has a good core of white flesh (Crane, 2013), Sugarloaf has an elevated juice content or quantity of 205.72 ml/kg of fruit, followed by MD-2 with values varying from 134.12-191.43 ml/kg of fruit and smooth cayenne with a minimum of 91.7-108.65 ml/kg of fruit. Sugarloaf has a greater content of Brix compared to MD2 and other varieties. It has a sweetness index of 15.14; followed by the 12.72 for MD-2 and the 6.98 for Smooth Cayenne (Wardy *et al.*, 2009).

2.1.2 Cayenne

Cayenne is one of the most widely grown varieties with high fruit quality in the world. It provides high production, resistance to gummosis, and contains spineless leaves. The content of smooth cayenne's total soluble sugars ranges from 12 to 16 ^{o}B. Smooth cayenne offers the ideal cylindrical shaped fruit for canning among the Cayenne variety. The fruit has high sugar and acid content (Crane, 2013). Its leaves are approximately 0.9 m at the base and top with some spines. The fruit weighs approximately 2.3-2.7 kg and is pale yellow to a yellow pulp. Hilo and Baronne de Rothschild are other members of the Cayenne group. The group Hilo produces no slips, while the group Baronne has spiny leaves (Samson, 1980).

2.1.3 Red Spanish

This sort of pineapple is not readily accessible as smooth cayenne. The leaves of the pineapple are spiny and the fruit weighs 0.9-1.8 kg. It has a pleasant aroma and pale-yellow flesh (Crane, 2013)

2.1.4 Queen

Also, like Smooth Cayenne, Queen cultivar is not commonly accessible. The leaves are spiny, curving backwards, with conical fruit shape (Samson, 1980). The yield of the fruit is moderate, weighing from 0.9 to 1.4 kg and has a golden yellow flesh, crisp texture and excellent flavour. The Queen Pineapple variety's TSS varies from 15 to 16 ^{o}Brix. The subgroups current in this cultivar are Natal Queen, Z Queen, Ripley Queen. (Crane, 2013).

2.1.5 MD 2

The MD 2 species is a hybrid generated with an average weight of between 1.3 and 2.5 kg from Cayenne Lisa in Hawaii. It has an intense orange to yellow-orange color and 15 to 17 ° Brix high sugar content. The fruit is sweet, compact and fibrous. The MD 2 pineapple has been increasingly considered as super sweet, self-mature and durable pineapple, as compared to the smooth cayenne, sugarloaf and other traditional pineapple varieties (Achuonjei *et al.,* 2003).

2.2 Nutritional composition of pineapple juice

Pineapple fruit is considered to be an attractive tropical fruit. It has higher juiciness, aroma, and significant health benefits. Pineapple has substantial content of Ca, K, vitamin C, carbohydrates, fiber, water, and several mineral properties that are beneficial for human health improvement. In addition, pineapple fruits have minimal sodium and sugar content (SabahelKhier *et al.,* 2010). Pineapple fruit has about 86.2 % moisture and 13 - 19 % of complete solids, with sucrose, glucose and fructose being the primary elements. Pineapple fruit has several essential minerals, which includes, manganese and copper.

Pineapple fruit is an outstanding source of vitamins and minerals. Approximately 16.2% of the daily vitamin C requirement can be provided by healthy matured pineapple fruit (Hemalatha and Anbuselvi, 2013). Vitamin C delays the advance of urinary tract illnesses during pregnancy and decreases the risk of certain cancers, such as cancer of the colon, esophagus and eye. Pineapple is also an excellent source of vitamin B1, vitamin B6, copper and dietary fiber. It hydrates the body and by drinking pineapple juice it reconstructs the immune system.

Also, pineapple juice is enriched with calcium, which is needed for the development of youth bone and the strengthening of bone in the elderly (Adikaram and Abayasekara, 2012). Pineapple enzymes may enhance blood circulation in those with decreased arteries. Pineapples are used to cure bronchitis and neck diseases. Pineapple is an outstanding toner in the brain that combats memory loss, sorrow, and melancholy. It is known that in curing constipation and irregular bowel movements, pineapple is very useful. Pineapple consumption helps eliminate intestinal worms and also keeps the intestines and kidneys clean.

In addition, the bromelain enzyme, which in pineapples is a natural antioxidant, with many wellness benefits. It is highly effective in treating wounds, strains and sprains as well as reducing swelling and pain. It may also assist to alleviate signs of rheumatoid arthritis and reduce postoperative swelling. This enzyme helps to break down amino acid protein bonds and promote good digestion (Walker *et al.*, 2002). Geographical location, cultural practices, seasonal harvesting and processing have been shown to contribute to varying nutritional composition in pineapple fruit (Sairi *et al.*, 2004).

2.3 Processing Technologies for Fruits

For hundreds of years, storage and handling technology have transformed fruit and vegetables into a safe, delicious, stable product (Rickman *et al.*, 2007). Various processing methods have been used not only to improve fruit and vegetables edibility and palatability but also to prolong their life expectancy. (Oey *et al.*, 2008). Widely used processing technologies include; freezing and refrigeration, and thermal pasteurization.

2.3.1 Freezing and Refrigeration

Freezing has been among the best methods in preserving the nutritional constituent in fruits and vegetables and their products. It maintains the actual appearance, taste and nutritional value of the fruit and vegetable. During freezing, water crystallization reduces the water interaction in the fruit cells, leading to a reduction in chemical and biochemical responses and microbial growth. Freezing also involves using low temperatures and reactions occur at reduced rates as the temperature is reduced. Freezing fruit and vegetables and their products slows down but does not prevent physical, chemical and biochemical responses from deteriorating. There is still a slow progressive change in sensory and nutritional quality during frozen storage, which is always noticeable after a while (De Ancos *et al.,* 2006). However, if at all times thorough controls are carried out, safe and high-quality products can be accomplished with optimum dietary values.

2.3.2 Thermal pasteurization

Thermal pasteurization methods are mainly dependent on heat generation outside the heating element, combustion of fuels or electrically resistive heaters and their return to the product through convection and convection procedures. (Pereira and Vicente, 2010). To date, heat application remains the most common method of processing to extend the shelf-life of liquid foods due to their ability to inactivate micro-organisms and spoilage enzymes (PPO, PME, etc.) (Zulueta *et al.*, 2013). Traditionally, at temperatures between 60 and 100 ºC, most preserved juices with a pH equal to or below 4.5 are processed thermally for a few seconds (Jay, 1992). A significant quantity of energy is transmitted to the food during this phase, which can in some instances lead to undesirable responses and sub-product formation.

(Rivas *et al.,* 2006). The following reviews the impacts on juice features of heat pasteurization.

Effect of pasteurization has been reported on pineapple, cashew and apple juice. It results in the degradation of bioactive compounds such as ascorbic acid and total carotenoids (Rattanathanalerk *et al.*, 2005; Zepka and Mercadante, 2009) as well as color changes. Pasteurization also led to a decrease in the levels of vitamin A and phenolics in the transformation of mango to puree while total carotenoids and ascorbic acid were reported to be stable though this depended on the severity of the process (Vásquez-Caicedo *et al.*, 2007).

2.4 Pineapple Physiological Maturity and Significance on Physicochemical Properties

Pineapple is non-climacteric, and therefore needs to be harvested at the right stage of maturity. Numerous studies have revealed that, maturity stage of harvesting most fruits will have different physicochemical quality.

Shamsudin *et al.*, (2009) indicated that many scientists recognized fruit maturity indices depending on size, weight or density measurements, physical characteristics such as properties of color, firmness and humidity and other chemical characteristics such as starch, sugar, protein content, or texture.

Changes in fruit color is the most evident mark of maturity according to Wills *et al.,* (2007). Consumers often make use of norms to determine whether a fruit is mature or not. Pineapple loses its green color as it matures through a catabolitic process. The structure of chlorophyll is affected by chlorophyllase enzyme (Dangl, 2000), which reveals carotenoids on the skin and therefore a greenish-yellow fruit appears. Soluble solids must decrease in most fruits between

11 and 18%, titratable acids must reduce by 0.5 to 1.6%, ascorbic acid by 20 and 65 mg/100 g, based on fruit cultivar and stage of maturity (Medina and García, 2005).

2.5 Effect of Maturity Stage on Total Soluble Solids

According to Zarei *et al.*, (2011), total soluble solids (TSS), mostly sugar products, considerably improved in three major stages of pomegranate fruit development. TSS content increased by approximately 1.5-fold between 54 days after full maturation and commercial harvest at 165 days after full maturation (Fawole and Opara, 2013). The TSS content of increased from 10.30 ^{o}Brix in immature pomegranate fruit at 20 days after fruit set to 19.56 ^{o}Brix in overmatured fruit at 140 days after full maturation (Zarei *et al.*, 2011).

Similarly for ' Ganesh ' cultivated in India, TSS concentrations improved by 13 percent in 40-day-old fruits, but they did not increase significantly by the 100th day of the growth when the TSS surpassed 15 percent (Kulkarni and Aradhya, 2005). A different accumulation pattern in pomegranate fruit in ' Taifi ' where the TSS content in immatured green fruits was 16.4 ^{o}Brix with very small increases in the TSS over the remaining fruit stage resulting in 16.9 ^{o}Brix during full maturity (Al-Maiman and Ahmad, 2002).

Dhar *et al.*, (2008) stated that pineapple fruits harvested at different maturity stages are not of uniform quality. Pineapple fruits that are destined for juicing should be harvested at the optimum maturity stage in order to obtain high-quality juice product.

Studies by Nadzirah *et al.*, (2013) to determine colour changes during storage and physiochemical properties of pineapple variety N36 of the maturity indices 1, 2 and 3, showed significant increase in L* (lightness), a* (redness) and b* (yellowness) values at each maturity stage during seven days storage. The pH of pineapple juice was in the range of 3.24 to 3.84. The titratable acidity and Total Soluble Solid (TSS) of pineapple juice extracts were in the range of 0.16 to 0.36%, 1.37 to 2.91% and 1.4 to 5.3 ^{o}Brix, respectively.

Glew *et al.*, (2003) studied the composition of minerals in the different phases of the development of Medlar (Mespilus Germanica) and found that in inmatured fruit, aluminum (Al), barium (Ba), iron (Fe), phosphorus (P), Strontium (Sr) and zinc (Zn), concentrations were higher, while potassium (K), calcium (Ca), magnesium (Mg) and copper (Cu) levels were low throughout fruit maturity.

Narain *et al.*, (2001), also studied the physical and chemical composition of the fruit Carambola (Averrhoa carambola L.) in three phases of development, observed that the reduction in sugar and tannin content of the fruit in all maturity phases is considerably distinct. The calcium content of matured fruits was significantly different from those for green and semi riped fruits

2.6 Physicochemical, nutritional, sensory and microbial quality changes of fruit juice during storage

Following processing, biochemical changes such as the concentration changes in vitamin C, sugars, soluble solids and phenols during storage of fresh-cut pineapple and juice are significant since they are used as primary quantitative parameters of quality (Gorny, 2001). The quality attributes frequently in fruit production are; solid soluble content, total or titratable acidity pH, water content, density and acidity ratio of soluble solids (Montero, 2010). During storage, the liquid foods undergo several major deterioration reactions, which include, ascorbic acid deterioration, cloud loss, microbial spoilage, off-flavour development, colour, texture, appearance and quality loss. (Esteve and Frígola, 2007). It is on this basis that the shelf-life of the product is ascertained.

Temperature management is the most important tool a food technologist or engineer can apply to extend shelf-life and maintain the quality of fruits and vegetables and their products. The degradation rate in quality is usually mitigated by reducing the temperature of product storage (Carpenter *et al.,* 1977) since the nutritional quality of food during storage has become a pressing problem (Burdurlu *et al.,* 2006). This important fact is of considerable significance to the consumer and processor who must have awareness on how to store the juice containers and when to consume them in order to derive maximum benefit from them. The following sub-section reviews the effects of storage on the quality attributes of fruit and vegetable juices.

2.7 Effect of storage on Vitamin C (Ascorbic acid)

Vitamin C is essential to the nutrition of our food and, due to its antioxidant capacity, and thus serves as an additive in a variety of foodstuffs, increasing food-quality, technological and nutritional values (Burdurlu *et al.*, 2006). However, ascorbic acid is an unstable compound and quickly decomposes under less desirable conditions (Lee and Coates, 1999).

Ascorbic acid retention is often used as an estimate for overall nutrient retention of food products (Davey *et al.,* 2000; Murcia *et al.,* 2000). The following articles review the effects of storage on ascorbic acid content.

In two commercial orange juices both fresh and after storage at 18, 28 and 38 ^{o}C for 2, 4 and 6 months, Vitamin C was examined for the effects of the storage condition and temperature on the vitamin C content (Klimczak *et al.*, 2007). The study reported that after six months of storage at 18, 28, and 38 ^{o}C, vitamin C content of the juice decreased by 21%, 31%, and 81%, respectively. In a related study, Kabasakalis *et al.*, (2000) studied the ascorbic acid degradation of different commercial fruit juices stored in closed containers and reported ascorbic acid losses ranging between 29-41% after four months of storage at room temperature.

Igual *et al.*, (2010) studied grapefruit juice stored at 4 and -18 ^{o}C for two months and reported that after 12 days of storage, ascorbic acid content decreased for juice samples irrespective of whether stored under refrigeration or frozen and after that maintained constant ascorbic acid content till the end of frozen storage. In the refrigerated juice, the proportion of ascorbic acid decreased significantly throughout storage.

Spínola *et al.*, (2013) studied the stability of L-ascorbic acid in passion fruit extracts during storage at 4, -20 and -80 ^{o}C and reported that at 4 ^{o}C, ascorbic acid remained stable for at least 24 h with the ascorbic acid recovery of 97.8% for extract solutions, but thereafter registered a notable decline throughout the entire study. During 1-week storage at -20 ^{o}C, ascorbic acid was stable with a recovery of 96.7%, while storage at -80 ^{o}C resulted in a minimal loss for up to 4 weeks (<2%). This study revealed that the best storage temperature to slow degradation for the fruit extract was -80 ^{o}C, followed by -20 ^{o}C, while 4 ^{o}C was not suitable for long-term storage in order to preserve ascorbic acid content.

2.8 Effect of storage on total phenolic content and antioxidant activity of fruit juice

A group of phytochemicals contributes to the total antioxidant activity of fruit juices. The change in the contents of these phytochemicals will result in the change in the total antioxidant activity of the product. The following reviews some studies on total phenolic and antioxidant changes during storage.

Klimczak *et al.,* (2007) investigated the effect of storage on polyphenol content and antioxidant activity of orange juice. The juice samples were stored at 18, 28 and 38 °C. It was reported that there was a decline in the polyphenol content and antioxidant content at the end of storage. After storage of the juices at 18, 28 and 38 ^{o}C for four months, the total phenolic content of the juices as determined by the Folic-Ciocalteu assay decreased by 7%, 11%, and 20% respectively. After two months of further storage, the juices showed a significant increase in the total phenolic content. This could be as a result of the reaction between Folin-ciocalteu reagent and some compounds that are formed during storage of the juice. (Vinson et al., 2001). The corresponding decrease of total antioxidant activity was 18%, 45% and 84% after six months of storage at the respective storage temperature regimes.

Igual *et al.,* (2010) studied the effect of thermal treatment and storage on the stability of organic acids and the functional value of grapefruit juice and reported that frozen (-18 ^{o}C) unpasteurized juice and conventionally pasteurized ones preserved about 75% and 20% of the total phenols and antioxidant capacity, respectively after 2 months of storage. The total antioxidant activity of the stored grapefruit decreased during storage for all kinds of treatment to the samples in this study.

Laorko, *et al.,* (2013) studied the effect of storage of micro-filtered non-pasteurized pineapple juice at 4, 27 and 37 ^{o}C on some phytochemical properties (vitamin C, total phenol content, antioxidant activity), and reported that the phytochemical properties and total phenolic content of the juice significantly decreased as storage time and temperature increased. This was maybe caused by polyphenolic oxidation and polymerization reaction, which resulted in decreasing the number of free hydroxyl groups measured by the Folin–Ciocalteu assay (Klopotek et al., 2005; Pacheco-palencia et al., 2007). The best storage temperature for non-thermally pasteurized and clarified pineapple juice was found to be 4 °C since this allowed the best pineapple juice quality preservation.

Arena *et al.,* (2001) studied the effect of storage on the total antioxidant capacity of blood orange juices and reported that the total antioxidant capacity of freshly squeezed juices remained unchanged during storage at 2 ^{o}C for 60 days. In comparison, juice reconstituted from concentrate had decreased antioxidant activity.

2.9 Effect of Storage on pH, Total Soluble Solids and Titratable Acidity of Fruit Juice

pH is a very essential quality attribute that describes the stability of bioactive compounds in fruit juice (Sánchez-Moreno *et al.*, 2003). The pH, titratable acidity and TSS of fruit juice may increase, decrease or remain statistically unchanged during storage as is reviewed below.

Chia *et al.,* (2012) evaluated the effect of storage of thermally pasteurized (80 ^{o}C, 10 minutes) pineapple juice at 4 ^{o}C for 13 weeks on the juice quality attributes and reported that pasteurized juice maintained a higher TSS during the whole period of storage compared to the untreated juice. The pH and TSS did not significantly change for the entire duration of storage for pasteurized samples while pH increased and TSS decreased significantly for unpasteurized juice samples.

Mgaya *et al.*, (2014) studied the effect of storage time and temperature on the physicochemical properties of pasteurized (82.5 ^{o}C, 20 minutes) roselle-fruit juice blend (with mango, papaya, and guava juice) and reported that TSS, pH and reducing sugars of the juice blends significantly increased during storage at 4 and 28 ^{o}C for 6 months. However, during storage of the juice blends, titratable acidity significantly decreased under the same storage conditions.

Nisar *et al.*, (2015) studied the effect of thermal treatments (65 ^{o}C, 30 minutes) of preservative treated apple pulp on the physicochemical characteristics during storage at 25 ^{o}C for 90 days and reported a significant increase in acidity and a simultaneous decrease in pH. The TSS of the juice also increased with increase in storage time. Acidity and pH are always interdependent in that the lower the pH, the higher is the acidity during storage at room temperature.

Cortés *et al.*, (2008) studied the physicochemical quality changes of pasteurized orange juices during seven weeks of refrigerated storage at 2 and 10 ^{o}C and reported a significant increase in pH values during storage while the brix values in pasteurized orange juice (11.4) did not change significantly during storage. Similar observation of increase in pH values of fruit juice has been reported by Del Caro *et al.*, (2004) for citrus segments and juices stored at 4 ^{o}C.

2.10Effect of storage on Microbial quality changes of fruit juice

The spoilage caused by microorganisms in juices includes cloud loss, off-flavour development, production of carbon dioxide, and changes in colour, texture, and appearance resulting in product degradation (Doyle, 2009). Juice pH, oxidation-reduction potential, water activity, nutrient availability, presence of antimicrobial compounds, and microflora competition are critical factors affecting juice spoilage (Aneja *et al.*, 2014). The most important variables influencing the degradation of juices include pH and water activity.

Lavinas *et al.*, (2006) reported reduced total aerobic bacteria as well as total fungi in cashew apple juice during frozen storage at -22 ^{o}C for 120 days while refrigerated juice stored for one week at 4 ^{o}C experienced reduced aerobic bacteria and increased yeast and mould during storage.

Patterson *et al.*, (2012) studied the microbiological quality and safety of carrot juice during refrigerated storage and found that in untreated juice, the total microbial counts increased rapidly and reached counts of 7 log CFU per ml within 4, 3 and 1 day from an initial count of 5.8 log CFU per ml during storage at 4, 8 and 12 ^{o}C, respectively. In comparison, high pressure processed carrot juice had reduced log reduction in microbial counts, and there was little growth of the survivors during storage at 4 ^{o}C for 22 days.

2.11 Effect of storage on organoleptic quality of fruit juice

Consumers attach great importance to the flavour, colour and organoleptic taste of fruit juice. According to Bhardwaj and Pandey (2011), organoleptic quality such as colour, flavour and nutritional value of fruit products generally decreases as the storage period of the fruit is increased. Fruits are known to develop undesirable characteristics during storage, as it developes off-flavour, undesirable taste, odour, etc. and this may have a significant effect on the consumer who can either accept or reject the product.

Oliveira *et al.*, (2012) studied the sensory changes of whole mango juice stored at 25, 35 and 45 ºC and found that the flavour, aroma and colour were the most affected by storage temperature and time and significantly decreased at the end of storage.

CHAPTER THREE

MATERIALS AND METHOD

Introduction

This chapter outlines the procedures followed to achieve the objectives of the study. It outlines the procedures for raw materials acquisition, processing, storage, and step-by-step methods followed for the analytical determinations of the pineapple juice quality attributes.

3.1 Experimental Site and Survey

The experiment was conducted at the laboratory of the School of Agriculture, University of Cape Coast. Analytical determinations of quality attributes were conducted at the Laboratories of the Department of Chemistry and the Department of Laboratory Technology of the University of Cape Coast.

A survey was undertaken at Blue Skies Limited. This was to gather information about the varieties of pineapple processed by the company, the time they harvest pineapple fruits, the maturity stage at which fruits are harvested and other preharvest and postharvest factors considered by Blue Skies as important.

3.2 Raw Materials Collection and Preparation

Pineapple fruit varieties (Smooth Cayenne and MD2) were obtained from Greenfields Limited, at Ekumfi in the Central Region of Ghana while Sugarloaf was obtained from Ataabadzi, in Elmina, which are all accredited farms of the Ministry of Food and Agriculture, Ghana. Pineapple fruits were harvested in the morning (7am-9am), afternoon (12pm-2pm), and the evening (5pm-7pm) at different maturity stages; immatured (100% green skin colour), matured (30-50% yellowing of eye on skin), and overmatured (80-100 yellowing of eye on skin).

Harvested fruits were sorted and cleaned to ensure that there were no bruised ones. Fruits were stored at both room temperature (25 ^{o}C) and in a refrigerator (5 ^{o}C) for three days prior to juicing.

3.3 Pineapple Juice Extraction

Cleaned pineapple fruits were manually peeled, with the crown and stem portions removed, using a stainless-steel knife. The fruits were sliced and blended using a laboratory fruit juicer (Kenwood 166-3). The obtained juice was immediately stored in the refrigerator prior to further analyses.

3.4 Experimental Design

A completely randomized design was deployed using a factorial design with 3 replications was used to study the effect of the factors on pineapple juice quality and safety. The coding was done from -1 to +1 through 0 for minimum, maximum, and centre point, respectively. The actual levels of the independent variables are shown in Table 1. The complete design of each variety consisted of 54 treatment combinations is shown in (Appendix 5)

Table 1: Independent Variables and their Level Used to Design the Experiment

Independent Variables	Levels		
	-1	0	+1
Maturity stage (X_1)	Immatured	Matured	Over matured
Time of harvest (X_2)	Morning	Afternoon	Evening
Storage (X_3)	Ambient		Refrigeration

3.5 Determination of Physicochemical Properties

The juice yield, pH, Total soluble solids, Titratable acidity, Ascorbic acid, Total phenolic content, total antioxidant activity, Total flavonoid, Moisture content, Mineral ash content, Protein content, Carbohydrate, Calcium, Magnesium, Phosphorous, Sodium, Potassium, as well microbial load and sensory quality of the juice were analyzed. The procedures used to carry out these quality determinations are described as follows:

3.5.1 pH

The pH of juice samples was recorded at ambient temperature condition using a digital pH meter (PHT- 01 ATC). The juice sample was put in a 100 ml beaker, thoroughly stirred, and the electrodes of pH meter immersed in the juice samples. The pH values were read from the screen of the pH meter.

3.5.2 Total Soluble Solids (TSS)

In determining the total soluble solids of the pineapple juice, a digital refractometer (Palm Abbe Digital Refractometer) was used. The obtained values were expressed in % Brix.

3.5.3 Titratable Acidity (TA)

Titratable acidity of the pineapple juice was obtained using a modified method of (Crisosto and Garner, 2001). This was done by pipetting 10 ml of the juice into a conical flask. 200 ml of 0.1N NaOH was poured into a burette and was titrated against the sample in the flask with three drops of phenolphthalein as an indicator. The obtained TA values was expressed as a percentage of citric acid (mole equivalent = 0.064). The formula used to calculate the titratable acidity is as follows:

% Titratable acidity = (0.1 x 0.064 ml of 0.1 N NaOH) x100/ g of sample (1)

3.5.4 Vitamin C Determination

In determining Vitamin C, a modified titration method as described by (Helmenstine, 2019) was used. 10 ml of pineapple juice was pipetted and diluted to 100 ml. 25 ml of the homogenized solution was pipetted into a 250 ml Erlenmeyer flask. 10 ml of 0.5M H_2SO_4 and 0.5g $NaHCO_3$ was added. The solution was then titrated against the standard, KIO_3 until a deep blue I.starch complex was obtained. Moles of iodine reacting were calculated using the equation below:

Ascorbic acid + $I_2 \Longrightarrow 2\ I^-$ + dehydroascorbic acid.

The concentration in mol/L of ascorbic acid in the solution obtained were calculated and then concentration in mg/100ml also calculated.

3.5.5 Total Phenolic Content

In determining total phenol content of the pineapple juice, a modified spectrophotometric method as described by Lu *et al.*, (2011) was used. 10 ml fruits juice was diluted to 100 ml with distilled water and filtered. 250 µl of the filtrate was pipetted into a colorimetric tube in triplicate. 750 µl of distilled water was added followed by 1 ml of 10 fold diluted Folin Ciocalteau phenol reagent. After 5 min, 1.5 ml of 10% Na_2CO_3 was added to the mixture. They were allowed to react for about 30 min in the dark after which the absorbance of the solution was read at 765 nm using UV mini 1240 (Shimazu Cooperation). A graph of standard calibration and unstandard calibration curve was plotted using Gallic acid equivalents in mg/100ml juice.

3.5.6 Total Antioxidant Capacity

In determining total antioxidant capacity, ethyl acetate, methanol, and water extracts of pineapple was evaluated by the method of Prieto *et al.,* (1999). An aliquot of 0.1 ml of sample solution (100 µg/ml) was combined with 1 ml of reagent solution (0.6 M sulfuric acid, 28 mM sodium phosphate, and 4 mM ammonium molybdate). The tubes were capped and incubated in a boiling water bath at 95 °C for 90 min. After the samples had cooled to room temperature, the absorbance of the aqueous solution of each was measured at 695 nm against a blank. A typical blank solution contained 1 mL of reagent solution and the appropriate volume of the same solvent used for the sample. It was incubated under the same conditions as the rest of the sample. For samples of unknown composition, water-soluble antioxidant capacity was expressed as equivalents of ascorbic acid (µmol/g) of extract

3.5.7 Total Flavonoid Content

The total flavonoid content was estimated using the colorimetric assay developed by Zhishen *et al.,* (1999) with some modifications. 250 µl of the juice extract was pipetted into colorimetric tubes and mixed with 750 µl distilled water. 1 ml of 5% w/v $NaNO_2$ was added. 1 ml of 10% $AlCl_3$ was added after 10 min incubation time followed by 2.5 ml of 1 M NaOH after 5 min. The final volume was made up to 6 ml with distilled water. The absorbance was read at 510 nm. The calibration curve was plotted using a standard solution of quercetin. The results were expressed as mg quercetin per L of juice.

3.6 Nutritional Content Determination

3.6.1 Moisture Content

The moisture content was determined with small changes according to the technique recommended by AOAC (1990). In the pre-weighed crucible, 5.0 grams of the samples were taken and placed in an air oven kept at 105 ^{o}C for 24 hours. The crucibles were immediately transferred into desiccators to be cooled and then, weighed. All the analyses were done in triplicates. For the fruit sample, the moisture content (%) was calculated as follows:

$$Moisture\ content = \frac{Loss\ in\ weight}{weight\ of\ sample} \qquad (2)$$

3.6.2 Mineral Ash Content

The content of mineral ash in the fruit samples was done by the Association of Official Analytical Chemists (AOAC, 1990) method. The samples were placed in a furnace at 550 ^{o}C for 6 hours. The crucibles were immediately transferred into desiccators to be cooled and then, weighed. Triplicates analyzes were performed. In the fruit sample, the mineral ash content (%) was calculated as follows:

$$\text{Ash} = \frac{\text{Loss in weight}}{\text{weight of sample}} * 100\% \qquad (3)$$

3.6.3 Protein Determination

Protein was determined by pipetting 2 ml of the juice into a numbered Kjeldahl digestion flask. About 4.5 ml of digestion mixture was added, and the sample was digested at 360 ^{o}Cfor two hours (AOAC, 1995). The digest was allowed to cool and diluted to 100 ml with distilled water. Twenty millilitres (20 ml) of the digested was immediately distilled after adding 10 ml of alkali mixture using 5 ml of boric acid as an indicator. 50 ml of the distillate was collected and titrated against

0.00712 M HCl until it turned to a pink colour which determined the endpoint. The remaining diluted digest was reserved for the mineral determination as described by the Food and Agriculture Organisation (FAO, 2008). Percentage protein was calculated using the formula;

$$\text{N (mg/L)} = \text{T (ml) x100/aliquot x Dilution factor} \tag{4}$$

$$\text{\% N} = \text{N (mg/L)/10000}$$

$$\text{\% Protein} = \text{\% N x 6.25}$$

3.6.4 Carbohydrate Determination

One millilitre of the pineapple juice was pipetted into a conical flask and diluted. It was kept in the conical flask for colour development. Two millilitres of standard glucose solution and the extract were pipetted into a set of boiling tubes, 10 ml of anthrone solution was rapidly added to the boiling tubes mixed thoroughly and cooled under running tap water or ice bath. The tubes were placed in a beaker containing boiling water in a dark fume cupboard for 10 minutes. The tubes were allowed to cool in cooled water in the dark (FAO, 2008; Page *et al.*, 1982). The optical density of the standards and the sample solution was measured at 625mn using the spectrophotometer. A calibration graph was prepared from the standards and used to obtain mg glucose in the sample aliquot.

$$\text{Soluble Carbohydrate (mg/L)} = \frac{C(mg)x\ 100}{aliquot} \text{ x Dilution factor} \tag{5}$$

Where; C (mg) = carbohydrate concentration from the graph.

3.6.5 Calcium Determination

An aliquot of 10 ml of the reserved digest was pipetted into a 250 ml conical flask, and 150 ml of distilled water was added. One ml each of potassium cyanide, hydroxylamine hydrochloride, potassium ferrocyanide, and triethanolamine were added. 20 ml of 10% sodium hydroxide was added to raise the pH, and then ten drops of calcon indicator were added to the solution and titrated against 0.005 M EDTA solution (AOAC, 1995).

$$Calcium\left(\frac{mg}{l}\right) = T * M * \frac{1000}{volume} * Molar\ mass * 10$$

3.6.6 Magnesium Determination

An aliquot of 10 ml of the reserved digest solution was pipette into a 250 ml conical flask. One hundred and fifty millilitres (150 ml) of distilled water was added. Fifteen millilitres (15 ml) of buffer solution was added and allowed to stand for a few minutes. One millilitre (1 ml) of each of potassium, cyanide, hydroxylamine hydrochloride, potassium ferrocyanide, and triethanolamine were added. Ten (10) drops of erichrome Black T indicator was added and titrated against 0.005 m EDTA solution (Keeney and Nelson, 1982).

$$Magnesium\left(\frac{mg}{l}\right) = T * M * \frac{1000}{volume} * Molar\ mass * 10$$

3.6.7 Phosphorus Determination

In determining the phosphorous of the samples, two millilitres of an aliquot of the digested sample solutions was pipette into a 25 ml volumetric flask. 2 ml of the blank digest was also added to the 2 ml of standard phosphorus solution to give it the same background as the digest. Ten millilitres of distilled water was added to the standards as well as the sample solutions. Four millilitres of reagent B made up of ascorbic acid and reagent (Keeney and Nelson, 1982). A reagent was added to the standard and sample solutions. Distilled water was added to the volumetric flask to make up to the volume of 25 ml and allowed to stand for about 15 minutes for the colour to develop. After colour development, the absorbances of the standard and sample solutions were determined using a spectrophotometer at a wavelength of 882mn. A standard calibration curve was plotted using their concentration against absorbance.

Calculations

If C = P mg/ml obtained from the graph then

$$P\ (mg/L) = \frac{Cmg\ x\ diluted\ factor}{aliquot} \qquad (6)$$

3.6.8 Sodium and Potassium Determination

Potassium and sodium concentrations in the digested samples were determined using the flame photometer. The following standard concentrations of both potassium and sodium were prepared 0, 2, 4, 6, 8, and 10 ug/ml (Keeney and Nelson, 1982). Both the working standards and the sample solutions were aspirated individually into the flame photometer and their emissions recorded. A calibration curve was plotted using the concentration and emissions of the working standards. The concentration of potassium and sodium in the sample solution were extrapolated from the curve using their emissions

$$K\ or\ Na\ (mg/L) = \frac{C(ppm)\ x\ solution\ volume}{aliquot} \qquad (7)$$

3.7 Sensory Evaluation of Pineapple Juice

Sensory evaluation of fresh pineapple fruit juice was performed in such a manner that sufficient room was created between taste panels so that discussion or facial expressions did not affect each other. Random letters coded the samples. Then a type of assessment was provided to the tasters. They were told to taste one sample at a moment and to record their answers. Panelists were provided adequate time

(10-15 min) between evaluating samples. In this experiment, an untrained panel of thirty members was chosen to assess the quality of fresh pineapple juice. The untrained panelists were blindly allocated to the samples and asked to score by the following characteristics: acceptability of colour, aroma, taste, aftertaste, and overall. The samples were assessed with a Hedonic scale of nine points (Sidel *et al.*, 2008). The samples were assessed using a 9-point hedonic scale ranging from 1 (extremely dislike) to 9 (extremely like).

3.8 Microbiological Analysis

Microbiological analysis was determined with slight modifications as described by other researchers (Chia *et al.*, 2012). Total plate counts (TPC) were determined using the plate count agar (PCA) (Merck, Germany) and the DRBC agar (Condalab, Spain) was used for yeast and mould counts. A sample of 0.1 ml of each serial dilution ($10-1$ to $10-5$) was spread across the solidified agar for both tests. The PCA plate was incubated at 37 degrees C for two days and at 5 degrees C for seven days, while the yeast and mould plate was incubated at 25 degrees C for five days. The results are expressed as log CFU/ml.

3.9 Statistical Analysis

In this study, General Linear Model (GLM) in Analysis of Variance (ANOVA) was performed in Minitab (Version 18.0) to determine the effects of maturity stage, time of harvest, and storage condition on physicochemical, nutritional, microbial and sensory characteristics of the three pineapple varieties. Tukey's test at $p< 0.05$ level was used to determine the significance between the treatment means.

CHAPTER FOUR

RESULTS

Introduction

In this study, a 3x3x2 factorial design was used to establish the effects of independent variables on physicochemical properties, mineral, sensory, and safety of pineapple juice of three varieties. The juice was processed using factors in Table 1. The results of the experiment were performed according to the general linear model in ANOVA for the interaction effects of maturity stage, time of harvest and storage on physicochemical properties of pineapple juice.

4.1 The Interaction Effect of Maturity Stage, Time of Harvest and Storage on Physicochemical Properties of Sugarloaf, Smooth Cayenne and MD-2 Pineapple Juice

4.1.1 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Physicochemical Properties of Sugarloaf Pineapple Juice

Table 2 presents results on physicochemical properties of sugarloaf pineapple fruit juice. The treatment OAR recorded highest mean (223.65 mg/kg) of total antioxidant content, followed by the treatments MMR (186.43 mg/kg), and UAA (179.64 mg/kg). The treatment MMA exhibited significantly lower (133.45 mg/kg) total antioxidant content among all treatments. However, no significant differences were found between treatment MMA and treatments UER (155.91 mg/kg), UEA (144.96 mg/kg), UAR (153.85 mg/kg), MEA (150.28 mg/kg), OMR (147.50 mg/kg), OEA (144.96 mg/kg) and UMA (140.99 mg/kg).

It was recorded that, total flavonoid content was significantly higher in treatment MMR (10.37 mg/l) than all other treatments except treatment UER (10.31

mg/l), which was statistically the same. The treatment OAR had a significantly lower (6.10 mg/l) amount of total flavonoid content from all the other treatment.

The treatment OAR recorded significantly higher mean (82.84 mg/l) of total phenol content. There was no statistical difference in total phenol content among treatments; OER (67.79 mg/l), UMR (67.34 mg/l), MAR (67.24 mg/l), MMR (66.14 mg/l), OAA (66.14 mg/l) and UAA (67.13 mg/l). The minimum total phenolic content was recorded in treatment MMA (52.08 mg/l). Treatment MMA was significantly different from treatment OER (67.79 mg/l), UMR (67.34 mg/l), MAR (67.24 mg/l), MMR (66.14 mg/l) and OAA (66.14 mg/l).

It was recorded that; Vitamin C content was significantly higher in treatment OAR (20.93 mg/100ml) than all other treatment. The treatment UMA had a significantly lower (9.98 mg/100ml) amount of Vitamin C.

The level of pH in Sugarloaf pineapple fruit juice was recorded to be significantly higher in treatment OAA (5.43). Treatment OAA was not significantly different from treatments OEA (5.37), OMA (5.30), UAA (5.30), OAR (5.30) and MER (5.30). No significant difference was observed in pH among treatments OMR (5.03), UEA (4.97), UMR (4.97), UAR (4.93) and MAA (4.90).

Among the sugarloaf, the treatments with the highest TSS (20.20 ^{o}B) was recorded in the treatment OAR, which was at par with treatments OAA (19.83). No significant difference was observed between treatment OAR (20.20 ^{o}B) and treatments OER (19.80 ^{o}B), OMA (19.23 ^{o}B), MEA (19.13 ^{o}B), UMA (18.97 ^{o}B), OEA (18.93 ^{o}B), OMR (18.60 ^{o}B), MMA (18.27 ^{o}B), MMR (17.87 ^{o}B), MER (17.63 ^{o}B) and MAA (17.20 ^{o}B). The treatment UER exhibited significantly minimum (14.90 ^{o}B) total soluble solids among all treatments.

Titratable acidity in Sugarloaf pineapple fruit was found not be significant among treatments. Treatment OAR exhibited the highest mean titratable acidity (1.10 %) which was not significantly different from the rest of the samples. Treatment OAA the minimum mean titratable acidity (0.70 %).

Table 2: Interaction effect of maturity stage, time of harvest and storage on physicochemical properties of Sugarloaf pineapple juice

Sample ID	TAC (mg/kg)	TF (mg/l)	TPC (mg/l)	Vit. C (mg/100m)	pH	TSS (°B)	TA % citric acid
UMA	140.99 ^{gh}	7.54 ^{i}	56.38 ^{bcd}	9.98 ^{j}	5.07 ^{efgh}	18.97 ^{ab}	0.93 ^{a}
MMA	133.45 ^{h}	9.35 ^{cde}	52.08 ^{d}	15.37 ^{h}	5.17 ^{cdef}	18.27 ^{abc}	1.02 ^{a}
OMA	169.84 ^{bcdef}	8.90 ^{def}	62.84 ^{bcd}	14.07 ^{i}	5.30 ^{abc}	19.23 ^{ab}	0.83 ^{a}
UAA	179.64 ^{bc}	9.64 ^{c}	67.13 ^{bc}	17.31 ^{c}	5.30 ^{abc}	16.33 ^{bc}	0.79 ^{a}
MAA	179.52 ^{bc}	7.94 ^{hi}	60.14 ^{bcd}	16.55 ^{def}	4.90 ^{i}	17.20 ^{abc}	0.91 ^{a}
OAA	175.16 ^{bcd}	8.65 ^{fg}	66.14 ^{bc}	19.77 ^{b}	5.43 ^{a}	19.83 ^{a}	0.70 ^{a}
UEA	155.48 ^{cdefgh}	9.39 ^{cd}	60.14 ^{bcd}	16.00 ^{gh}	4.97 ^{ghi}	16.13 ^{bc}	0.77 ^{a}
MEA	150.28 ^{defgh}	7.88 ^{hi}	59.41 ^{bcd}	16.40 ^{ef}	5.27 ^{bcd}	19.13 ^{ab}	0.78 ^{a}
OEA	144.96 ^{fgh}	9.28 ^{cde}	55.37 ^{bcd}	15.10 ^{h}	5.37 ^{ab}	18.93 ^{ab}	0.81 ^{a}
UMR	173.45	9.38 ^{cde}	67.34 ^{bc}	19.43 ^{b}	4.97 ^{ghi}	16.37 ^{bc}	0.92 ^{a}
MMR	186.43 ^{b}	10.37 ^{a}	66.14 ^{bc}	17.10 ^{cd}	5.20 ^{cde}	17.87 ^{abc}	0.89 ^{a}
OMR	147.50 ^{efgh}	9.74 ^{bc}	54.19 ^{cd}	16.81 ^{cde}	5.03 ^{fghi}	18.60 ^{ab}	0.91 ^{a}
UAR	153.85 ^{cdefgh}	8.32 ^{fgh}	59.81 ^{bcd}	16.33 ^{fg}	4.93 ^{hi}	16.27 ^{bc}	0.95 ^{a}
MAR	172.10 ^{bcde}	8.07 ^{ghi}	67.24 ^{bc}	15.16 ^{h}	5.13 ^{def}	16.00 ^{bc}	0.76 ^{a}
OAR	223.65 ^{a}	6.10 ^{j}	82.84 ^{a}	20.93 ^{a}	5.30 ^{abc}	20.20 ^{a}	1.10 ^{a}
UER	155.91 ^{cdefgh}	10.31 ^{ab}	59.96 ^{bcd}	14.01 ^{i}	5.10 ^{efg}	14.90 ^{c}	0.88 ^{a}
MER	164.01 ^{bcdefg}	7.50 ^{i}	62.21 ^{bcd}	15.10 ^{h}	5.30 ^{abc}	17.63 ^{abc}	0.88 ^{a}
OER	174.56 ^{bcd}	8.80 ^{ef}	67.79 ^{bc}	15.57 ^{h}	5.20 ^{cde}	19.80 ^{a}	0.97 ^{a}
MEAN	160.04	8.73	62.62	16.16	5.16	17.87	0.88
CV %	5.0	2.3	6.7	5.0	1.1	6.2	19.4

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$).

4.1.2 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Physicochemical Properties of Smooth Cayenne Pineapple Juice

For Smooth Cayenne pineapple variety, the treatment OAR recorded the highest mean total antioxidant content of 172.90 mg/kg. This was not significantly higher than treatment MAA (163.81 mg/kg), UMR (161.31 mg/kg), UER (159.56 mg/kg), OMA (157.18 mg/kg) and OMR (151.91 mg/kg) (Table 3). The minimum total antioxidant content was recorded in treatment MAR (97.18 mg/kg). There was no significant difference between treatment MAR and treatments OAA (117.06 mg/kg) and UMA (115.68 mg/kg).

Treatment OAR recorded highest mean total flavonoid content of 10.76 mg/l which was statistically not different from treatment MMR (10.73 mg/l). No significant difference was found between treatment MMR and treatments UMR (10.30 mg/l), UAA (10.22 mg/l), UEA (10.12 mg/l), MMA (9.99 mg/l) OEA (9.94 mg/l), OMA (9.80 mg/l), MAA (8.91 mg/l), MAR (8.62 mg/l) and MEA (8.60 mg/l). The treatment UAR recorded the minimum (6.30 mg/l) amount of Total flavonoid content. Also, this was not significantly different from treatment UMA (8.16 mg/l), OMR (8.08 mg/l), UER (7.22 mg/l), MER (6.57 mg/l) and OER (6.45 mg/l).

Treatment MAA recorded the highest mean (62.73 mg/l) of Total phenol content. There were no significant difference between treatment MAA and treatments OMR (60.54 mg/l), OAR (60.00 mg/l), OMA (57.58 mg/l) and UER (57.58 mg/l). The minimum total phenol content was recorded in treatment MAR (31.35 mg/l).

Treatment OMA recorded highest mean (19.46 mg/100ml) of Vitamin C content, which was significantly not different from treatments UAA (19.18 mg/100ml), MEA (19.12 mg/100ml) and MAA (18.87 mg/100ml). The treatment UMA recorded the minimum (15.31 mg/100ml) amount of Vitamin C content.

Treatment OAA recorded the highest mean (5.20) of pH value. There was no significant difference between treatment OAA and treatments MAR (5.10) and UAA (5.10). The minimum pH value was recorded in treatment UMA (4.80).

The total soluble solids in Smooth Cayenne pineapple variety was recorded to be significantly higher in treatment OMR (14.37 ^oB). There is no significant difference between treatment OMR and treatment MAA (14.20 ^oB), OEA (14.03 ^oB), UEA (14.00 ^oB), OMA (13.90 ^oB), MMA (13.47 ^oB), OAA (13.43 ^oB), OER (13.43 ^oB), MER (13.33 ^oB), UMR (13.33 ^oB). The minimum TSS value was recorded in treatment UAR (9.37 ^oB).

Level of titratable acidity in Smooth Cayenne pineapple fruit juice was recorded to be significantly higher in treatments OAR and MEA (1.35 % citric acid) as compared to treatments UER and MER (0.79 % citric acid), which were the least.

Table 3: Interaction effect of maturity stage, time of harvest and storage on physicochemical properties of Smooth cayenne pineapple juice

Sample ID	TAC (mg/kg)	TF (mg/l)	TPC (mg/l)	Vit. C (mg/100ml)	pH	TSS (^{o}B)	TA % citric acid
UMA	115.68^{ef}	8.16^{bcde}	40.36^{fg}	15.31^{k}	4.80^{d}	13.00^{ab}	0.98^{ab}
MMA	146.83^{bcd}	9.99^{ab}	50.21^{de}	17.36^{fghi}	4.87^{cd}	13.47^{a}	0.80^{b}
OMA	157.18^{abcd}	9.80^{ab}	57.58^{abcd}	19.46^{a}	4.83^{cd}	13.90^{a}	0.94^{ab}
UAA	138.89^{cde}	10.22^{ab}	49.45^{de}	19.18^{ab}	5.10^{ab}	11.20^{ab}	0.96^{ab}
MAA	163.81^{ab}	8.90^{abc}	62.73^{a}	18.87^{abc}	4.87^{cd}	14.20^{a}	0.98^{ab}
OAA	117.06^{ef}	9.33^{abc}	36.06^{gh}	18.04^{def}	5.20^{a}	13.43^{a}	1.09^{ab}
UEA	148.81^{bcd}	10.12^{ab}	53.24^{bcde}	18.10^{def}	4.83^{cd}	14.00^{a}	1.04^{ab}
MEA	135.40^{de}	8.60^{abcd}	45.91^{ef}	19.12^{abc}	4.80^{d}	12.93^{ab}	1.35^{a}
OEA	140.56^{bcd}	9.94^{ab}	52.02^{cde}	18.50^{cde}	4.93^{cd}	14.03^{a}	0.81^{b}
UMR	161.31^{abc}	10.30^{ab}	50.08^{de}	18.45^{cde}	4.93^{cd}	13.33^{a}	0.98^{ab}
MMR	144.60^{bcd}	10.73^{a}	51.32^{de}	18.56^{bcd}	4.80^{d}	13.13^{ab}	0.94^{ab}
OMR	151.91^{abcd}	8.08^{bcde}	60.54^{ab}	17.88^{efg}	4.90^{cd}	14.37^{a}	1.11^{ab}
UAR	134.25^{de}	6.30^{e}	48.38^{ef}	17.55^{fgh}	4.87^{cd}	9.37^{b}	0.97^{ab}
MAR	97.18^{f}	8.62^{abcd}	31.35^{h}	14.57^{l}	5.10^{ab}	12.37^{ab}	0.96^{ab}
OAR	172.90^{a}	10.76^{a}	60.00^{abc}	16.60^{j}	4.83^{cd}	13.00^{ab}	1.35^{a}
UER	159.56^{abc}	7.22^{cde}	57.58^{abcd}	16.69^{ghij}	4.80^{d}	12.20^{ab}	0.79^{b}
MER	134.01^{de}	6.57^{de}	49.70^{de}	17.19^{ghij}	4.97^{bc}	13.33^{a}	0.79^{b}
OER	140.40^{cd}	6.45^{de}	51.62^{cde}	17.22^{ghij}	4.93^{cd}	13.43^{a}	1.03^{ab}
MEAN	142.24	8.89	49.89	17.70	4.91	13.04	0.99
CV %	5.2	8.1	5.3	1.2	0.9	9.8	14.9

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$).

4.1.3 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Physicochemical Properties of MD-2 Pineapple Juice

Table 4 presents data on MD-2 pineapple variety. It was recorded that, treatment UAR had the highest mean (484.36 mg/kg) of Total antioxidant content, which was not statistically higher than treatment OMR (479.46 mg/kg). UMA treatment had a significantly lower (161.07 mg/kg) amount of total antioxidant content from all the other treatment.

Total flavonoid content of MD-2 pineapple fruit was recorded to be significantly higher in treatment UER (11.02 mg/l). No significant difference was observed between treatment UER and treatments MMR (10.53 mg/l), MMA (10.34 mg/l), OMR (10.30 mg/l), UAA (10.23 mg/l), UMR (10.16 mg/l), OMA (10.13 mg/l) and UEA (10.04 mg/l). Treatment OAR exhibited significantly minimum (5.69 mg/l) total flavonoid content among all treatments.

It was recorded that, treatment UER had the highest mean (78.16 mg/l) of total phenol content, which was significantly not higher than treatments UAA (75.86 mg/l), MMA (75.08 mg/l), MMR (71.67 mg/l), OEA (70.92 mg/l) and OMA (70.17 mg/l). OAR treatment had a significantly lower (40.63 mg/l) amount of total phenol content from all the other treatment.

Vitamin C content of MD-2 pineapple fruit was recorded to be significantly higher in treatment MEA (47.29 mg/100ml). This was significantly not higher than treatment MMR (41.68 mg/100ml), OMR (40.75 mg/100ml), MAA (38.81 mg/100ml), UEA (37.59 mg/100ml). Treatment UMA exhibited significantly minimum (14.16 mg/100ml) Vitamin C content among all treatments.

It was recorded that, treatment UMA and UAA recorded significantly higher pH (4.90). Treatment MAA had a significantly lower (4.60) pH value from all the other treatment.

It was recorded that, treatment MER had the highest mean (14.50 ^oB) of total soluble solids. This was significantly not different from TSS value obtained from treatment, OER (14.17 ^oB), OEA (14.13 ^oB), MMA (14.07 ^oB), OMR (14.07 ^oB), OMA (14.07 ^oB), OAA (13.33 ^oB), MAA (13.33 ^oB) and UER (13.00 ^oB). Treatments UMA and UAA had a significantly lower (10.00 ^oB) amount of TSS.

Titratable acidity in MD-2 pineapple variety was recorded to be significantly highest in treatment OAA (1.21 %), followed by treatment OMR (1.14 %), MEA (0.99 %), OEA (0.99 %), MER (0.99 %) and OMA (0.97 %). The minimum titratable acidity was recorded in treatment UMR (0.76 %).

Table 4: Interaction effect of maturity stage, time of harvest and storage on physicochemical properties of MD-2 pineapple juice

Sample ID	TAC (mg/kg)	TF (mg/l)	TPC (mg/l)	Vit. C (mg/100ml)	pH	TSS (°B)	TA % citric acid
UMA	161.07^{k}	7.33^{g}	53.33^{i}	14.16^{e}	4.90^{a}	10.00^{e}	0.83^{c}
MMA	348.98^{d}	10.34^{abc}	75.08^{abcd}	34.87^{bcd}	4.80^{b}	13.17^{abc}	0.82^{c}
OMA	335.83^{ef}	10.13^{abcd}	$70.17^{abcdefg}$	29.88^{d}	4.70^{c}	14.07^{a}	0.97^{abc}
UAA	222.56^{j}	10.23^{abc}	75.86^{abc}	34.63^{bcd}	4.90^{a}	10.00^{e}	0.84^{c}
MAA	327.25^{f}	8.03^{efg}	66.47^{cdefgh}	38.81^{abcd}	4.60^{d}	13.33^{ab}	0.94^{bc}
OAA	241.15^{i}	8.86^{def}	64.01^{efgh}	30.64^{cd}	4.70^{c}	13.33^{ab}	1.21^{a}
UEA	284.31^{g}	10.04^{abcd}	67.36^{bcdefg}	37.59^{abcd}	4.70^{c}	11.33^{de}	0.91^{bc}
MEA	286.78^{g}	7.85^{fg}	65.83^{cdefgh}	47.29^{a}	4.70^{c}	11.67^{cd}	0.99^{abc}
OEA	367.36^{c}	9.25^{bcde}	70.92^{abcde}	34.75^{bcd}	4.80^{b}	14.13^{a}	0.99^{abc}
UMR	263.74^{h}	10.16^{abcd}	60.56^{ghi}	33.88^{bcd}	4.70^{c}	11.67^{cd}	0.76^{c}
MMR	408.23^{b}	10.53^{ab}	71.67^{abcde}	41.68^{ab}	4.80^{b}	12.33^{bcd}	0.86^{c}
OMR	479.46^{a}	10.30^{abc}	77.04^{ab}	40.75^{abc}	4.61^{d}	14.07^{a}	1.14^{ab}
UAR	484.35^{a}	7.15^{g}	61.32^{fghi}	38.83^{abcd}	4.70^{c}	12.00^{bcd}	0.89^{bc}
MAR	283.39^{g}	8.14^{efg}	65.08^{defgh}	34.16^{bcd}	4.80^{b}	12.33^{bcd}	0.92^{bc}
OAR	287.62^{g}	5.69^{h}	40.63^{j}	29.64^{d}	4.70^{c}	14.00^{a}	0.89^{bc}
UER	339.22^{df}	11.02^{a}	78.16^{a}	33.94^{bcd}	4.70^{c}	13.00^{abc}	0.86^{c}
MER	331.37^{ef}	7.12^{g}	56.91^{hi}	33.99^{bcd}	4.70^{c}	14.50^{a}	0.99^{abc}
OER	331.74^{ef}	9.07^{cdef}	67.91^{bcdefg}	30.88^{cd}	4.70^{c}	14.17^{a}	0.86^{c}
MEAN	321.36	8.96	66.02	34.47	4.7	12.73	0.93
CV %	1.2	1.1	9.9	1.2	0.1	4.1	9.5

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$).

4.2 The Interaction Effect of Maturity Stage, Time of Harvest and Storage on Nutrient Content of Sugarloaf, Smooth Cayenne and MD-2 Pineapple Juice

4.2.1 The Interaction Effect of maturity stage, time of harvest and storage on Nutrient Content of Sugarloaf pineapple juice

From Table 4, the Sugarloaf pineapple fruit was recorded to have a moisture content ranging from 74.27% to 87.51%. The maximum mean (87.51 %) value of moisture content was observed in treatment UER, followed by treatment MAR (86.72 %), UER (86.16 %), UEA (85.89 %) and MER (84.97 %). The minimum moisture content was observed to be OMA (74.27 %).

Treatment UMR recorded the highest (0.56%) mean value for ash content, followed by the treatment UMA (0.44%), OER (0.41%), OMA (0.38%) and MAA (0.38%). The lowest (0.11%) mean value for ash content was observed in the treatment UAR. No significant differences were observed among the treatment means.

Among the treatments for sugarloaf pineapple juice, MMR recorded the highest mean (14.30 mg/ml) value for carbohydrate, followed by the treatment UMR (13.86 mg/ml), MEA (12.85 mg/ml) OAA (12.61 mg/ml) and OEA (12.57 mg/ml). The lowest mean (9.90 mg/ml) value for carbohydrate was observed in the treatment UMA.

The crude protein content among treatments for the sugarloaf pineapple juice was observed to be significantly higher in treatment UAR (7.97 %). The lowest (3.92 %) means protein content was observed in treatment MER.

Treatment OMR recorded highest mean (0.85 mg/ml) of magnesium content. The treatment UAA recorded the minimum (0.31 mg/ml) amount of magnesium.

Treatment OMA recorded highest mean (6.06 mg/ml) of calcium content. Treatments UEA and UAA recorded the minimum (1.06 mg/ml) amount of calcium.

Treatment UMR recorded highest mean (0.20 mg/ml) of phosphorus content. Treatment UMA recorded the minimum (0.11 mg/ml) amount of phosphorus.

Treatment OAR recorded highest mean (1.61 mg/ml) of potassium content. Treatment MER recorded the minimum (1.09 mg/ml) amount of potassium.

Treatment OAR recorded highest mean (0.474 mg/ml) of sodium content which was not significantly different from treatment UAR (0.472 mg/ml). Treatments UMA and MER recorded the minimum (0.173 mg/ml) amount of sodium.

Table 5: Interaction effect of maturity stage, time of harvest and storage on Nutrition of Sugarloaf pineapple juice

Sample ID	Na (mg/l)	K (mg/l)	P (mg/l)	Ca (mg/l	Mg (mg/l)	Protein (%)	CHO (mg/l)	Moisture (%)	Ash (%)
UMA	0.173^{f}	1.155^{k}	0.108^{m}	1.448^{fg}	0.611^{c}	4.547^{h}	9.904^{l}	82.46^{ab}	0.44^{a}
MMA	0.346^{d}	1.186^{j}	0.127^{kl}	1.152^{h}	0.550^{d}	4.992^{f}	11.187^{ij}	79.81^{ab}	0.34^{a}
UAA	0.301^{e}	1.276^{i}	0.184^{c}	1.057^{h}	0.307^{g}	4.695^{g}	11.808^{g}	74.27^{b}	0.38^{a}
MAA	0.340^{d}	1.285^{i}	0.132^{j}	2.154^{d}	0.614^{c}	5.461^{d}	10.589^{k}	83.21^{ab}	0.26^{a}
OAA	0.382^{c}	1.413^{g}	0.138^{i}	2.555^{c}	0.672^{b}	5.328^{e}	12.607^{d}	83.93^{ab}	0.38^{a}
UEA	0.387^{c}	1.449^{f}	0.191^{b}	1.057^{h}	0.553^{d}	6.547^{b}	11.610^{h}	83.2^{ab}	0.28^{a}
MEA	0.385^{c}	1.543^{c}	0.174^{d}	1.974^{de}	0.547^{de}	5.328^{e}	12.852^{c}	85.89^{a}	0.19^{a}
OEA	0.382^{c}	1.352^{h}	0.152^{h}	1.493^{fg}	0.501^{e}	4.383^{i}	12.569^{d}	83.72^{ab}	0.26^{a}
UMR	0.429^{b}	1.477^{e}	0.200^{a}	1.643^{f}	0.617^{c}	5.000^{f}	13.856^{b}	85.38^{a}	0.56^{a}
MMR	0.432^{b}	1.482^{e}	0.153^{h}	1.954^{de}	0.365^{f}	5.027^{f}	14.301^{a}	84.74^{ab}	0.2^{a}
OMR	0.340^{d}	1.285^{i}	0.126^{kl}	4.659^{b}	0.854^{a}	5.297^{e}	11.132^{j}	83.71^{ab}	0.21^{a}
UAR	0.472^{a}	1.576^{b}	0.193^{b}	1.283^{gh}	0.590^{cd}	7.969^{a}	12.138^{f}	86.16^{a}	0.11^{a}
MAR	0.429^{b}	1.411^{g}	0.169^{e}	2.154^{d}	0.547^{de}	5.633^{c}	11.198^{i}	86.72^{a}	0.22^{a}
OAR	0.474^{a}	1.610^{a}	0.160^{g}	1.894^{e}	0.583^{cd}	5.320^{e}	11.846^{g}	82.1^{ab}	0.27^{a}
UER	0.382^{c}	1.350^{h}	0.171^{e}	1.147^{h}	0.550^{d}	6.570^{b}	11.141^{j}	87.51^{a}	0.17^{a}
MER	0.173^{f}	1.089^{l}	0.128^{k}	1.593^{f}	0.501^{e}	3.922^{j}	12.374^{e}	84.97^{ab}	0.22^{a}
OER	0.338^{d}	1.482^{e}	0.163^{f}	1.638^{f}	0.380^{f}	5.023^{f}	12.398^{e}	81.79^{ab}	0.41^{a}
MEAN	0.6	1.39	0.16	2.05	0.55	5.35	11.93	83.53	0.29
CV %	1.1	0.3	0.3	2.7	2.2	0.4	0.2	4	61.1

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$)

4.2.2 The Interaction Effect of Maturity Stage, Time of Harvest and Storage on Nutrition of Smooth Cayenne Pineapple Juice

Table 6 shows the nutrition components of smooth cayenne. The smooth cayenne pineapple fruits was observed to have a moisture content ranging from 86.66 to 91.63%. Treatment UAA was observed to have a maximum mean (91.63 %) value of moisture content, which is followed by treatment UEA (91.35 %). The minimum level of moisture content was observed to be appreciably lower in treatment OAR (86.66 %).

Treatment MAA recorded the highest (0.43%) mean value for ash content, followed by the treatment OAA (0.41%), MER (0.38%), MMA (0.36%) and UMR (0.34%). The lowest (0.13%) mean value for ash content was observed in the treatment UAR. No significant differences were observed among the treatment means.

The carbohydrate content for smooth cayenne pineapple was observed to be significantly higher in treatment MMR (14.88 mg/ml), followed by treatment UMR (14.27 mg/ml). The lowest mean (10.33 mg/ml) value of carbohydrate was observed in treatment UMA.

The crude protein content among treatments for the smooth cayenne pineapple juice was observed to be significantly higher in treatment OMA (7.96 %). The lowest (4.20 %) mean crude protein content was observed in treatment UMR.

Treatment MAR recorded highest mean (0.73 mg/ml) of magnesium content. The treatment OER recorded the minimum (0.30 mg/ml) amount of magnesium which was not significantly different from treatment UAR (0.32 mg/ml)

Treatment MAR recorded highest mean (4.70 mg/ml) of calcium content. Treatments MER recorded the minimum (1.03 mg/ml) amount of calcium.

Treatment OAR recorded highest mean (0.19 mg/ml) of phosphorus content. Treatment UAA recorded the minimum (0.12 mg/ml) amount of phosphorus.

Treatment OMA recorded highest mean (1.419 mg/ml) of potassium content. Treatment MER recorded the minimum (0.909 mg/ml) amount of potassium which was not significantly different from treatment UMA (0.910 mg/ml)

Treatments MMR and MER recorded highest mean (0.71 mg/ml) of sodium content. Treatments UMA recorded the minimum (0.34 mg/ml) amount of sodium.

Table 6: Interaction effect of maturity stage, time of harvest and storage on Nutrition of Smooth cayenne pineapple juice

Sample ID	Na (mg/l)	K (mg/l)	P (mg/l)	Ca (mg/l)	Mg (mg/l)	Protein (%)	CHO (mg/l)	Moisture (%)	Ash (%)
UMA	0.340^{h}	0.910^{n}	0.152^{hi}	1.789^{ef}	0.538^{b}	4.204^{n}	10.329^{m}	91.51^{ab}	0.24^{a}
MMA	0.433^{g}	1.042^{k}	0.141^{k}	1.283^{hi}	0.346^{ij}	4.367^{m}	11.472^{h}	89.29^{abc}	0.36^{a}
OMA	0.479^{f}	1.419^{a}	0.145^{jk}	3.347^{b}	0.535^{b}	7.961^{a}	11.325^{i}	90.01^{abc}	0.27^{a}
UAA	0.433^{g}	1.000^{l}	0.120^{m}	1.278^{hi}	0.368^{hi}	7.485^{b}	11.756^{g}	91.63^{a}	0.25^{a}
MAA	0.500^{ef}	1.134^{hi}	0.173^{d}	1.648^{fg}	0.456^{cde}	7.047^{c}	10.890^{k}	87.11^{bc}	0.43^{a}
OAA	0.624^{c}	1.162^{g}	0.169^{de}	2.360^{c}	0.459^{cd}	7.985^{a}	12.878^{c}	87.56^{abc}	0.41^{a}
UEA	0.717^{a}	1.392^{b}	0.165^{ef}	1.202^{ij}	0.474^{c}	5.492^{j}	12.187^{e}	91.35^{ab}	0.2^{a}
MEA	0.481^{f}	1.199^{f}	0.145^{jk}	1.388^{hi}	0.459^{cd}	5.235^{k}	12.698^{d}	89.06^{abc}	0.19^{a}
OEA	0.526^{e}	1.107^{j}	0.190^{ab}	2.154^{d}	0.410^{efgh}	5.766^{h}	12.286^{e}	86.81^{c}	0.24^{a}
UMR	0.619^{c}	1.242^{d}	0.188^{bc}	1.869^{e}	0.416^{defg}	4.196^{n}	14.265^{b}	89.11^{abc}	0.34^{a}
MMR	0.710^{a}	1.280^{c}	0.184^{c}	1.458^{gh}	0.468^{c}	6.555^{d}	14.876^{a}	88.84^{abc}	0.27^{a}
OMR	0.614^{cd}	0.909^{n}	0.157^{gh}	2.129^{d}	0.343^{ij}	5.781^{h}	11.046^{j}	87.14^{bc}	0.29^{a}
UAR	0.529^{e}	1.219^{e}	0.131^{l}	1.884^{e}	0.319^{j}	4.844^{l}	11.808^{g}	88.2^{abc}	0.13^{a}
MAR	0.426^{g}	1.049^{k}	0.152^{hi}	4.699^{a}	0.723^{a}	5.625^{i}	10.712^{l}	87.32^{abc}	0.31^{a}
OAR	0.624^{c}	1.152^{gh}	0.193^{a}	1.298^{hi}	0.428^{cdef}	4.399^{m}	12.033^{f}	86.66^{c}	0.28^{a}
UER	0.576^{d}	0.887^{o}	0.154^{hi}	1.668^{f}	0.380^{ghi}	6.438^{e}	11.415^{hi}	89.27^{abc}	0.21^{a}
MER	0.710^{a}	1.131^{i}	0.162^{fg}	1.032^{j}	0.404^{fgh}	6.110^{g}	12.746^{d}	86.69^{c}	0.38^{a}
OER	0.669^{b}	0.976^{m}	0.150^{ij}	1.298^{hi}	0.301^{j}	6.266^{f}	12.807^{cd}	87.38^{abc}	0.31^{a}
MEAN	0.56	1.23	0.16	1.88	0.43	5.88	12.08	88.61	0.28
CV %	1.6	0.3	0.8	2.6	2.7	0.3	0.2	1.6	33.7

Note: Results expressed as means. Means in the same line with different letter are significantly different (p<0.05)

4.2.3 The Interaction Effect of Maturity Stage, Time of Harvest and Storage on Nutrition of MD2 Pineapple Juice

From table 7 it was observed that treatment MAA statistically recorded a maximum mean (92.80 %) value of moisture content, followed by treatment UAA (92.38 %). The minimum moisture content in MD-2 pineapple juice was recorded in treatment MER (86.81 %).

From table 7, the ash content of MD-2 pineapple juice was observed to vary significantly among the treatments. The mean ash content values were recorded to be higher in treatment UAR (0.62%), followed by treatment MER (0.61%). The UAA treatment was observed to record the lowest (0.23%) mean ash content value. This was not significantly different from the mean ash content value recorded for treatment MMA (0.33%) and OAR (0.33%).

For MD-2 pineapple variety, the mean carbohydrate content was observed to be higher in treatment MMR (12.19 mg/ml). Treatment UMA was observed to record the lowest (6.67 mg/ml) means carbohydrate value.

For MD-2 pineapple variety, the mean crude protein content was observed to be higher in treatment UMA (9.066 %). Treatment MEA was observed to record the lowest (4.227 %) mean crude protein content.

Treatment OAA recorded highest mean (0.267 mg/ml) of magnesium content which was statistically not different from MAA (0.240) and MER (0.237 mg/ml). The treatments UEA and OEA recorded the minimum (0.061 mg/ml) amount of magnesium.

Treatment OAA recorded highest mean (1.51 mg/ml) of calcium content. Treatments MMA, UEA and UER recorded the minimum (0.95 mg/ml) amount of calcium.

Treatment OAA recorded highest mean (0.22 mg/ml) of phosphorus content. Treatment MEA recorded the minimum (0.12 mg/ml) amount of phosphorus.

Treatment OAA recorded highest mean (1.57 mg/ml) of potassium content. Treatment MER recorded the minimum (0.81 mg/ml) amount of potassium.

Treatment MAR recorded highest mean (1.02 mg/ml) of sodium content. Treatments MMA and UMR recorded the minimum (0.24 mg/ml) amount of sodium.

Table 7: Interaction effect of maturity stage, time of harvest and storage on Nutrition of MD2 pineapple juice

Sample ID	Na (mg/l)	K (mg/l)	P (mg/l)	Ca (mg/l)	Mg (mg/l)	Protein (%)	CHO (mg/l)	Moisture (%)	Ash (%)
UMA	0.431^{f}	1.245^{fg}	0.152^{h}	1.052^{efg}	0.182^{ab}	9.066^{a}	6.67^{k}	90.99^{abc}	0.5^{ab}
MMA	0.240^{g}	1.319^{de}	0.136^{k}	0.952^{g}	0.122^{bc}	5.164^{j}	7.15^{j}	89.55^{abc}	0.33^{ab}
OMA	0.574^{de}	1.175^{h}	0.164^{d}	1.112^{defg}	0.115^{bc}	4.547^{l}	9.29^{b}	91.38^{abc}	0.34^{ab}
UAA	0.548^{e}	1.210^{gh}	0.159^{e}	1.202^{cdef}	0.125^{bc}	5.859^{de}	8.19^{f}	92.38^{ab}	0.23^{b}
MAA	0.881^{b}	1.425^{c}	0.140^{j}	1.157^{cdefg}	0.240^{a}	5.484^{h}	8.90^{c}	92.8^{a}	0.51^{ab}
OAA	0.667^{c}	1.573^{a}	0.220^{a}	1.513^{a}	0.267^{a}	5.633^{gh}	7.84^{h}	88.99^{abc}	0.41^{ab}
UEA	0.433^{f}	1.104^{i}	0.152^{h}	0.952^{g}	0.061^{c}	5.797^{ef}	7.40^{i}	90.15^{abc}	0.38^{ab}
MEA	0.383^{f}	1.281^{ef}	0.120^{l}	1.002^{fg}	0.122^{bc}	4.227^{m}	7.06^{j}	90.15^{abc}	0.47^{ab}
OEA	0.671^{c}	1.283^{ef}	0.157^{fg}	1.052^{efg}	0.061^{c}	5.164^{j}	8.76^{d}	87.96^{abc}	0.4^{ab}
UMR	0.240^{g}	1.354^{d}	0.169^{c}	1.313^{bc}	0.125^{bc}	5.695^{fg}	8.44^{e}	90.93^{abc}	0.35^{ab}
MMR	0.386^{f}	1.027^{j}	0.184^{b}	1.052^{efg}	0.188^{ab}	5.797^{ef}	12.19^{a}	89.11^{abc}	0.46^{ab}
OMR	0.290^{g}	1.281^{ef}	0.155^{g}	1.052^{efg}	0.122^{bc}	4.539^{l}	9.01^{c}	88.58^{abc}	0.51^{ab}
UAR	0.574^{de}	1.478^{b}	0.146^{i}	1.298^{bcd}	0.185^{ab}	5.945^{de}	8.09^{f}	89.09^{abc}	0.62^{a}
MAR	1.024^{a}	1.442^{bc}	0.152^{h}	1.102^{efg}	0.182^{ab}	5.320^{i}	8.07^{fg}	89.09^{abc}	0.49^{ab}
OAR	0.250^{g}	1.208^{gh}	0.159^{ef}	1.102^{efg}	0.182^{ab}	6.734^{c}	8.39^{e}	87.58^{bc}	0.33^{ab}
UER	0.150^{h}	1.113^{i}	0.134^{k}	0.952^{g}	0.122^{bc}	7.039^{b}	7.93^{h}	88.72^{abc}	0.55^{ab}
MER	0.624^{cd}	0.805^{k}	0.139^{j}	1.413^{ab}	0.237^{a}	4.852^{k}	7.89^{h}	86.81^{c}	0.61^{a}
OER	0.388^{f}	1.173^{h}	0.136^{k}	1.107^{efg}	0.119^{bc}	5.961^{d}	7.96^{gh}	88.85^{abc}	0.48^{ab}
MEAN	0.49	1.25	0.15	1.13	0.15	5.71	8.30	89.62	0.44
CV %	2.4	0.9	0.4	4.0	13.8	0.7	0.4	1.8	27.8

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$)

4.3 Microbial Quality of Minimally Processed Pineapple Juice of Sugarloaf, Smooth Cayenne and MD-2 Pineapple Varieties

4.3.1 Microbial quality of Sugarloaf pineapple juice

Figure 1 shows the mean differences of yeast and mould count (YMC) and Total Plate Count (TPC) of sugarloaf pineapple juice. The mean yeast and mould count (CFU/ml) among the treatments for sugarloaf pineapple juice were observed to range from 2.342 to 4.227 log CFU/ml, while the mean Total Plate Count (TPC) ranged from 0.00 to 4.164 log CFU/ml. Among treatments in Sugarloaf pineapple juice, OMR showed the highest mean (4.227 log CFU/ml) of yeast and mould count, followed by MAR (4.053 log CFU/ml). UMA was observed to contain the least (2.342) amount of yeast and moulds. There were some levels of Total Plate count contamination in the sugarloaf pineapple juice for all treatments except for treatment MMR. The highest total plate counts (4.164 log CFU/ml) were observed in treatment MAR.

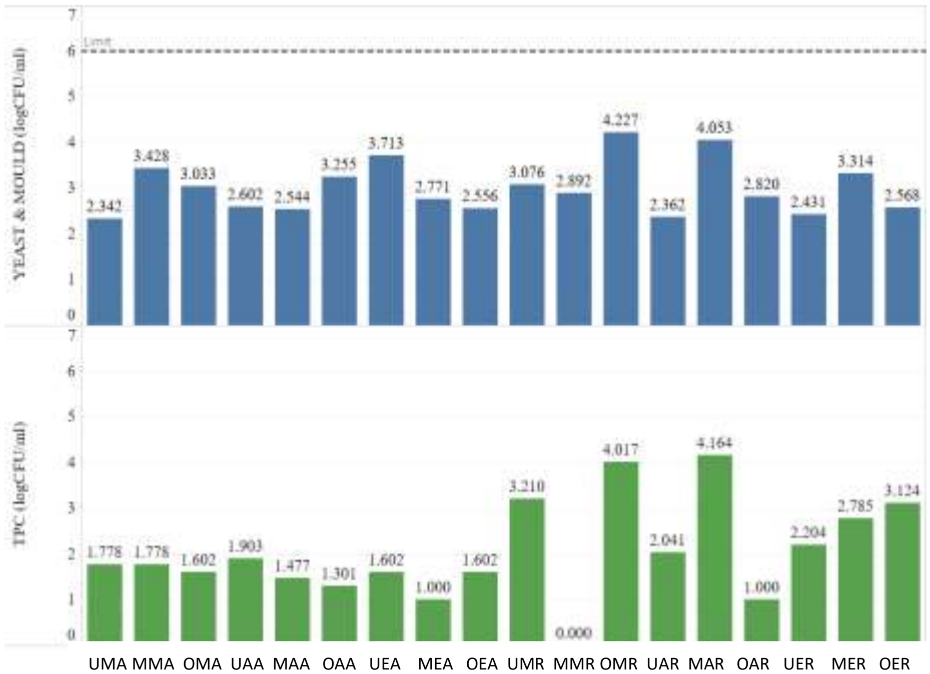

Figure 1: YMC and TPC of Sugarloaf pineapple juice. The dashed-line shows microbial shelf life limit.

4.3.2 Microbial Quality of Smooth Cayenne Pineapple Juice

Figure 2 shows the mean differences of yeast and mould count (YMC) and Total Plate Count (TPC) of Smooth cayenne pineapple juice. There were some level of yeast and mould contamination in the treatments for smooth cayenne pineapple juice. It was observed that treatment UAA showed the highest mean of 4.180 log CFU/ml, and the least yeast and mould count (1.903 log CFU/ml) observed in treatment UMR. The total plate count for smooth cayenne among the treatments was observed to be minimally when unripe fruits were harvested in the afternoon and stored in the ambient prior to processing. Treatment UER recorded the highest TPC of 3.004 log CFU/ml.

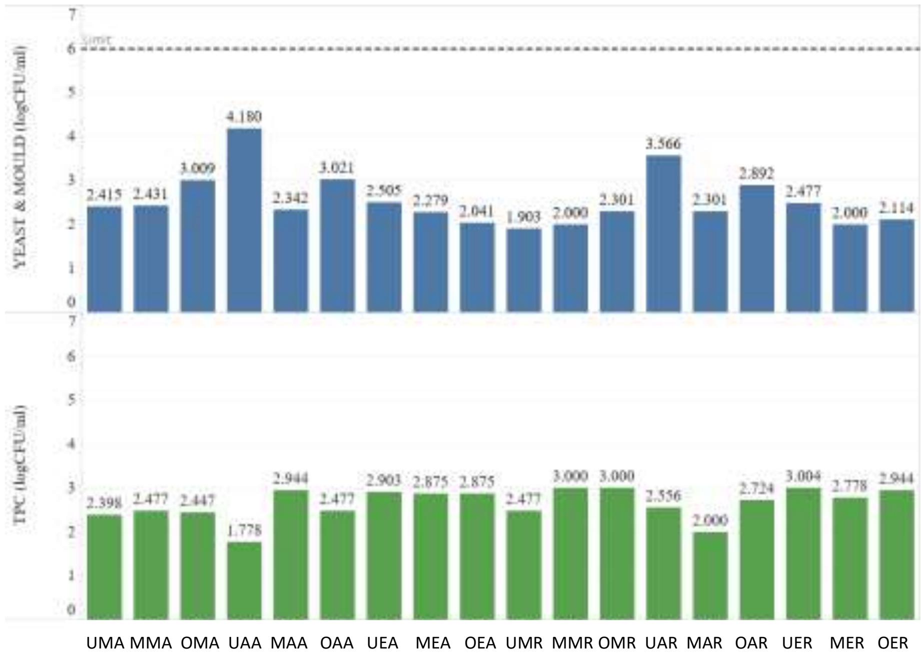

Figure 2: YMC and TPC of Smooth cayenne pineapple juice. The dashed-line shows microbial shelf life limit.

4.3.3 Microbial Quality of MD-2 Pineapple Juice

Figure 3 shows the mean differences of Yeast and Mould count (YMC) and Total Plate Count (TPC) of MD-2 pineapple juice. Similarly, there was yeast and mould contamination among treatment for MD-2 pineapple juice. Treatment MER recorded the highest mean (3.225 log CFU/ml) of yeast and mould count while treatment MMA recorded the least yeast and mould counts (2.079 log CFU/ml). The highest TPC were observed in treatment OAA (2.556 log CFU/ml). There were total plate count for treatments MAA, MEA, OEA, UMR, MAR, and UER.

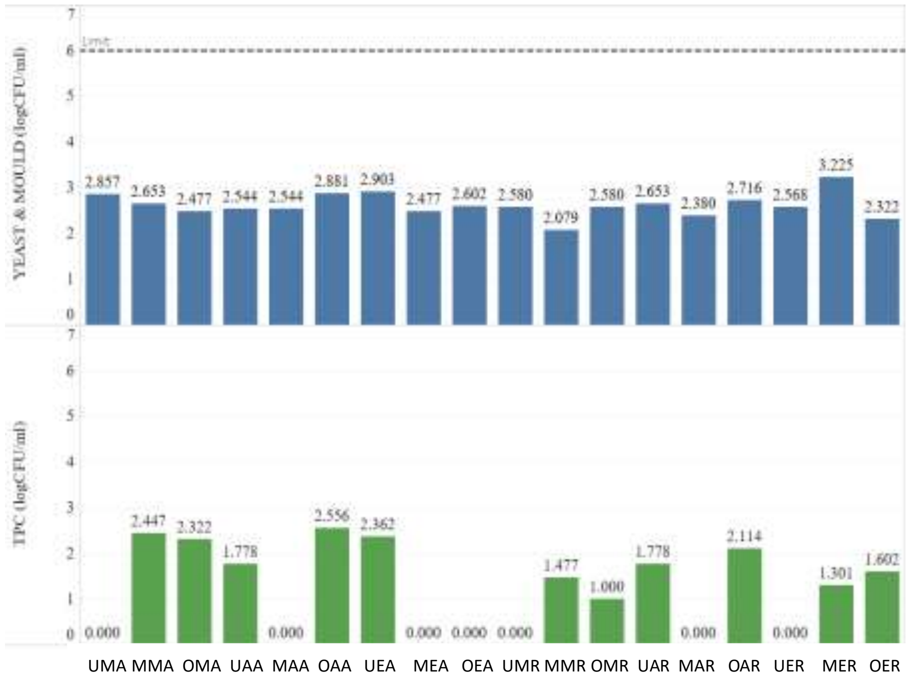

Figure 3: YMC and TPC of Smooth cayenne pineapple juice. The dashed-line shows microbial shelf life limit.

4.4 The Interaction Effect of Maturity Stage, Time of Harvest and Storage on Sensory Attributes of Sugarloaf, Smooth Cayenne and MD-2 Pineapple Juice

4.4.1 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Sensory Attributes of Sugarloaf Pineapple Juice

Table 8 shows the mean scores for the sensory attributes of pineapple juice from Sugarloaf pineapple fruit. The sensory qualities color, aroma, taste, after taste and overall acceptability, were analyzed using 30 panelists. The sensory attributes differed significantly (p<0.05) between the treatments for taste, after taste and overall acceptability of the pineapple juice. According to Tukey's Studentized Range Test, the treatment OMA recorded high mean scores of 8.0 for taste; which means the panel like treatment OMA very much (Appendix 6A). The mean values of after taste (7.8) and overall acceptability (8.1) of OMA was highest compared to other treatments. The aftertaste of treatment OMA was preferred very much by the consumers as compared to the other treatments. No significant difference were observed between the means of the colour and aroma of the juice prepared from the various treatments, however consumers liked moderately (7.2) the colour of OER.

Table 8: Interaction effect of maturity stage, time of harvest and storage on Sensory Attributes of Sugarloaf pineapple juice Interaction

Sample ID	Colour	Aroma	Taste	After taste	OA
UMA	6.5 ^{a}	6.4 ^{a}	7.3 ^{ab}	7.1 ^{ab}	7.4 ^{ab}
MMA	6.1 ^{a}	6.2 ^{a}	7.4 ^{ab}	6.7 ^{abc}	7.2 ^{ab}
OMA	6.5 ^{a}	6.3 ^{a}	8.0 ^{a}	7.8 ^{a}	8.1 ^{a}
UAA	5.9 ^{a}	5.4 ^{a}	5.9 ^{abc}	6.4 ^{abc}	7.0 ^{abc}
MAA	6.7 ^{a}	6.8 ^{a}	6.4 ^{abc}	6.4 ^{abc}	7.4 ^{ab}
OAA	6.8 ^{a}	6.1 ^{a}	6.7 ^{abc}	7.2 ^{ab}	7.6 ^{ab}
UEA	6.2 ^{a}	5.2 ^{a}	5.4 ^{bc}	5.6 ^{abc}	6.1 ^{bc}
MEA	6.9 ^{a}	5.9 ^{a}	6.9 ^{abc}	6.6 ^{abc}	7.3 ^{ab}
OEA	6.2 ^{a}	6.2 ^{a}	6.2 ^{abc}	6.6 ^{abc}	7.0 ^{abc}
UMR	6.5 ^{a}	6.1 ^{a}	5.6 ^{bc}	5.5 ^{bc}	6.2 ^{bc}
MMR	5.9 ^{a}	6.5 ^{a}	5.8 ^{bc}	6.0 ^{abc}	6.6 ^{abc}
OMR	6.1 ^{a}	5.8 ^{a}	5.9 ^{abc}	6.1 ^{abc}	6.7 ^{abc}
UAR	6.6 ^{a}	6.6 ^{a}	6.4 ^{abc}	6.7 ^{abc}	6.8 ^{abc}
MAR	6.8 ^{a}	6.9 ^{a}	6.9 ^{abc}	6.5 ^{abc}	7.2 ^{ab}
OAR	7.0 ^{a}	6.0 ^{a}	5.0 ^{c}	6.4 ^{abc}	6.9 ^{abc}
UER	5.9 ^{a}	5.9 ^{a}	5.7 ^{bc}	6.3 ^{abc}	5.4 ^{c}
MER	6.3 ^{a}	6.4 ^{a}	6.4 ^{abc}	4.9 ^{c}	6.3 ^{bc}
OER	7.2 ^{a}	6.3 ^{a}	5.9 ^{abc}	5.8 ^{abc}	6.8 ^{abc}
Control	6.1 ^{a}	6.8 ^{a}	6.3 ^{abc}	5.7 ^{bc}	6.8 ^{abc}
MEAN	6.43	6.20	6.32	6.33	6.88
CV %	23.1	24.5	28.0	26.4	21.1

Note: Results expressed as means. Means in the same line with different letter are significantly different (p<0.05)

4.4.2 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Sensory Attributes of Smooth Cayenne Pineapple Juice

From Table 9, the mean scores of sensory attributes for smooth cayenne pineapple juice were evaluated. Color of processed pineapple juice was liked very much (Appendix 6A) for treatment OMA (7.5), while the Aroma of OMR (6.9) was liked moderately by the consumers. No significant differences were observed in the taste of the juice, however, liked slightly the taste of OMR (6.8) and OER (6.8).The aftertaste of treatment OMR was liked moderately by the panelists. The overall acceptability mean score among treatments effects on pineapple juice was recorded to be high for treatment OMR. The overall acceptability of treatment OMR was liked very much (Appendix 6A) by the panelists.

Table 9: Interaction effect of maturity stage, time of harvest and storage on Sensory Attributes of Smooth cayenne pineapple juice

Sample ID	Colour	Aroma	Taste	After taste	OA
UMA	5.1 d	5.5 abc	5.4 a	5.1 b	5.4 b
MMA	5.9 abcd	5.6 abc	5.5 a	5.2 b	5.8 ab
OMA	7.5 a	6.1 ab	6.0 a	5.8 ab	6.2 ab
UAA	5.7 bcd	5.5 abc	5.5 a	4.9 b	5.1 b
MAA	7.1 abc	6.3 ab	6.8 a	6.2 ab	6.6 ab
OAA	6.7 abcd	5.4 abc	5.2 a	5.4 b	5.9 ab
UEA	5.5 bcd	4.9 bc	5.0 a	5.1 b	5.0 b
MEA	6.6 abcd	5.9 abc	5.7 a	5.9 ab	6.2 ab
OEA	6.2 abcd	5.8 abc	6.4 a	6.2 ab	6.5 ab
UMR	5.1 d	5.2 abc	5.7 a	5.9 ab	5.9 ab
MMR	6.1 abcd	6.3 ab	6.7 a	6.2 ab	6.6 ab
OMR	7.2 ab	6.9 a	6.8 a	7.4 a	7.6 a
UAR	5.9 abcd	5.3 abc	5.6 a	5.4 b	5.6 b
MAR	6.7 abcd	6.2 ab	6.7 a	6.2 ab	6.8 ab
OAR	6.7 abcd	6.0 ab	5.9 a	6.6 ab	6.3 ab
UER	5.4 cd	4.0 c	4.8 a	4.7 b	4.9 b
MER	5.9 abcd	6.1 ab	6.0 a	6.3 ab	6.7 ab
OER	7.1 abc	6.4 ab	6.8 a	6.4 ab	6.5 ab
Control	3.2 e	5.4 abc	5.0 a	4.7 b	4.9 b
MEAN	6.08	5.73	5.87	5.77	6.03
CV %	23.3	27.4	28.9	29.1	26.9

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$)

4.4.3 Interaction Effect of Maturity Stage, Time of Harvest and Storage on Sensory Attributes of MD-2 Pineapple Juice

Table 10 shows the interaction effect of maturity stage, harvest time, and storage temperature on sensory attributes of MD-2 pineapple juice. The sensory attributes differed significantly (p<0.05) between treatment for colour, aroma, taste, after taste and overall acceptability of the pineapple juice. According to Tukey's Studentized Range Test, the treatment OAA recorded high mean scores of 7.2 for colour. That is, the panelists liked moderately the colour of the juice (Appendix 6A). The panelists liked moderately the aroma of OAA (7.1) and OAR (7.0) but disliked very much (Appendix 6A), the aroma of UMA (2.5). The taste aftertaste and overall acceptablity of OAA was liked moderately by the panellists (Appendix 6A).

Table 10: Interaction effect of maturity stage, time of harvest and Sensory Attributes of MD-2 pineapple juice

Sample ID	Colour	Aroma	Taste	After taste	OA
UMA	5.7 ^{abc}	2.5^{h}	4.2^{de}	4.9 ^{cde}	4.4 ^{fg}
MMA	6.1^{abc}	5.8 ^{bcdef}	6.4 ^{abc}	6.6 ^{abc}	6.5 ^{abcd}
OMA	6.8^{abc}	6.8 ^{bc}	5.7 ^{abcd}	6.0 ^{abcd}	6.4 ^{abcd}
UAA	4.9^{c}	3.7 ^{gh}	3.2 ^{e}	3.6 ^{e}	4.2 ^{g}
MAA	5.7^{abc}	5.4 ^{bcdef}	5.2 ^{bcd}	5.2 ^{bcde}	5.4 ^{cdefg}
OAA	7.2^{a}	7.1 ^{ab}	7.1 ^{a}	7.0 ^{ab}	7.4 ^{ab}
UEA	4.9 ^{c}	4.7 ^{fg}	4.6 ^{cde}	4.4 ^{de}	5.2 ^{defg}
MEA	5.1 ^{bc}	4.9 ^{efg}	4.2 ^{de}	4.4 ^{de}	4.5 ^{efg}
OEA	6.9 ^{ab}	6.7 ^{bcd}	6.6 ^{ab}	6.6 ^{abc}	7.0 ^{abc}
UMR	5.9 ^{abc}	5.2 ^{cdefg}	4.6 ^{cde}	5.4 ^{abcde}	5.2 ^{defg}
MMR	6.7 ^{abc}	6.9 ^{abc}	6.6 ^{ab}	6.5 ^{abc}	6.7 ^{abcd}
OMR	6.1 ^{abc}	5.9 ^{bcdef}	5.8 ^{abcd}	5.8 ^{abcd}	5.8 ^{bcdefg}
UAR	6.5 ^{abc}	6.0 ^{bcdef}	5.4 ^{abcd}	5.1 ^{cde}	5.8 ^{bcdefg}
MAR	6.2 ^{abc}	6.5 ^{bcde}	6.3 ^{abc}	5.6 ^{abcd}	6.4 ^{abcd}
OAR	6.7 ^{abc}	7.0 ^{ab}	6.9 ^{ab}	6.6 ^{abc}	7.1 ^{abc}
UER	5.8 ^{abc}	5.3 ^{cdefg}	5.9 ^{abcd}	5.6 ^{abcd}	5.9 ^{abcdef}
MER	6.2 ^{abc}	6.2 ^{bcdef}	6.1 ^{abcd}	6.1 ^{abcd}	6.5 ^{abcd}
OER	5.9 ^{abc}	5.0 ^{defg}	5.5 ^{abcd}	5.5 ^{abcd}	6.2 ^{abcde}
Control	5.6^{abc}	8.5 ^{a}	7.2 ^{a}	7.2 ^{a}	7.6 ^{a}
MEAN	6.05	5.79	5.66	5.69	6.01
CV %	26.5	23.90	26.5	28	23.40

Note: Results expressed as means. Means in the same line with different letter are significantly different ($p<0.05$)

CHAPTER FIVE

DISCUSSIONS

5.1 The Interaction Effect of Maturity Stage, Time of Harvest and Storage Temperature on Physicochemical Properties of Pineapple Juice

5.1.1 Total Antioxidant Activity

In this study, the antioxidant activities of MD-2 pineapple fruit was examined to be relatively higher as compared to those in Sugarloaf and Smooth cayenne. (Table 2, 3 and 4). The stage of maturation is one of the factors which may influence fruit antioxidant activity (Fawole and Opara, 2013). The antioxidant activity recorded in the present study increased when the fruit maturity stage advanced. From appendices 1A, 2A, and 3A, maturity stage and time of harvest had a significant positive influence ($p \leq 0.05$) on total antioxidant content in Sugarloaf, Smooth cayenne and MD-2 pineapple varieties. Although there was an increase in total antioxidant content as the fruit was maturing, there was inconsistency in total antioxidant mean values of all three pineapple varieties. The research by Gordon *et al.,* (2012) also found that the antioxidant activity was inconsistent at various maturity stages in acai fruit in accordance with its total phenolic content. The overmatured pineapple fruit would likely lose their functional qualities, and therefore have a reduced antioxidant activity compared with matured fruit (Gruz *et al.*, 2011). The fruit maturing stage is therefore an important factor in the assessment of its antioxidant potential.

5.1.2 Total Flavonoids

From Tables 2, 3 and 4, there was no significant difference found between the unmatured, matured and overmatured stage of pineapple on total flavonoid but, there was a decrease in total flavonoid as the fruit advanced in maturity. This finding was similar to the report of Fawole and Opara (2013) who indicated that overall flavonoids content decreased with advanced maturity on pomegranate fruits.

The time of harvest was found to have a significant influence on the total flavonoid concentration of the pineapple fruit (Table 2, 3 and 4). However, no variation was observed between the morning and evening time of harvest of fruits.

4.1.3 Total Phenol

The study showed that Total phenol content varied significantly during fruit maturation of both Sugarloaf and Smooth Cayenne pineapple varieties, which is in agreement with other researchers (Chirinos *et al.*, 2010; Pineli *et al.*, 2011; Tlili *et al.*, 2015). This was not similar to the MD-2 pineapple variety, as total phenolic content was observed to decrease as the fruit was maturing. These findings agree in part with the results reported by Gordon *et al.*, (2012) and Palafox-Carlos *et al.*, (2012) as total phenol content decreased with maturity.

The research by Soumya and Ramana (2014) also found that during fruit growth and maturation, the overall phenol content of four cultivars was distinctive between the four icebox watermelon fruit. The significant variations in the TPCs of such fruits during maturation may also influence the degree of biosynthetic phenolic compounds.

5.1.4 Vitamin C

The concentration of vitamin C in Sugarloaf, Smooth cayenne, and MD-2 pineapple was observed to be significantly influenced by maturity stage, time of harvest, and storage condition (Appendices 1D, 2D, and 3D). Among the pineapple varieties, the MD-2 variety of showed considerably more vitamin C compared to Sugarloaf and Smooth cayenne at all maturity stages. Study by Lu *et al.,* (2014) among pineapple types also showed that, MD-2 pineapple fruit contained the highest amount of ascorbic acid. Although the matured stage of pineapple was observed to record higher vitamin C content, the results obtained from the study was inconsistent. This agrees partly to a study by Arif *et al.,* (2010) which determined the contents of vitamin C in berries at three different maturity stages. They found a higher concentration of vitamin C in the matured stage. The vitamin C contents obtained during the unmatured stage was slightly lower than the vitamin C contents at the overmatured stage of maturity. Research conducted by (Irwin and Hutchins, 1976: FAO, 2004), vitamin C requirement of human beings increases with age. Children need a concentration of 25mg per day of vitamin C, however, 8 g of vitamin C a day can help avoid issues of scurvy in infants, making pineapple juice a rich source of vitamin C that is adequate to prevent scorbutic signs in infants

5.1.5 pH

pH is an indicator of inner maturity and can be used to determine the best harvest time (Vinson *et al.,* 2010). The pH in the pineapple varieties varied greatly in different maturity stage. It has been discovered that pH increases as the fruit matures. Compared with the Smooth Cayenne and the MD-2 pineapple, the highest pH level was noted in Sugarloaf pineapples. The combined effect of stages of maturity, time of harvest, and storage conditions were also found to be significant on pH.

5.1.6 Total Soluble Solids

The high content of TSS is desirable for fruits (Ercisli, 2007), making pineapples suited for processing with their remarkably high TSS content estimated to be 12.7 ^{o}Brix. In addition, the determination of the ^{o}brix is a reliable way of determining maturity and best harvest time. In the course of fruit maturity and maturing, there is a change in total soluble solids, according to Moneruzzaman *et al.,* (2008). The total soluble solid increases from mature green stage to yellow maturity stage.

The total soluble solids content of the pineapple fruits juice observed in this study was higher in Sugarloaf pineapple fruit as compared to the Smooth cayenne and MD-2 pineapple variety. From appendices 1F, 2F, and 3F, maturity stage and time of harvest had significant influence ($p \leq 0.05$) in Sugarloaf, Smooth Cayenne, and MD-2 pineapple varieties. An earlier research carried out by Ding and Syazwani (2016) showed that the maturity of a pineapple improves its sugar content. Results from the study showed a significant increase in total soluble solids (TSS) ($p<0.05$) with an increase in maturity levels for all varieties of pineapple.

Similar results for other pineapples, such as Sarawak (George *et al.,* 2015) and Queen (Truc *et al.,* 2008) have been recorded in previous research. Pineapple TSS increased as a result of starch conversions to sugars such as glucose, sucrose and fructose at ripening (mature Green) and matured yellow / orange (Fernando and De Silva, 2000; Kittur *et al.*, 2001; Zhu *et al.*, 2017).

5.1.7 Titratable Acidity

Titratable acidity has a distinct sour taste and flavour and is often seen as a reliable indicator of overall fruit quality (Bhat *et al.,* 2011). From the study, it was observed that the titratable acidity of the Sugarloaf and Smooth Cayenne pineapple was not significantly influenced by maturity stage (Appendix A7 and B7). On the other hand, MD-2 pineapple was influenced by maturity stage (Appendix C7). The titratable acidity increased significantly increase as the MD-2 pineapple fruit is overmatured. This is consistent with past studies on strawberries and mulberries (Mahmood *et al.,* 2012).

Preceding research, however, proposed that a significant drop in the titratable acidity of pineapples was observed after maturing and as the fruit matures (Dhar *et al.*, 2008). This is also in agreement with the study, as TA of Sugarloaf and Smooth Cayenne pineapple fruit was observed to decrease as the fruit was maturing. This decrease in titrable acidity could be due to the use in the fruit respiratory process of these constituent acids (citric and malic acid) (Nagar, 1994).

5.2 The Interaction Effect of Maturity Stage, Time of Harvest and Storage Temperature on Nutrition of Pineapple Juice

5.2.1 Minerals

Fruits are potential sources of vitamins and minerals for human health benefit (Sagdic *et al.,* 2006). Physicochemical characteristics and mineral composition of fruit not only differ by botanical type, growing methods, and climate, but also alter with pre-harvest maturity, maturity status, and post-harvest storage (Glew *et al.*, 2003; Lozano, 2006; Narain *et al.*, 2001).

In the present study, the variations in mineral content among the pineapple varieties were observed to be significantly influenced by the treatment combination. The mineral composition of Na and P minerals were observed to be high in MD-2 pineapple juice, with low K content. The low levels of K can be linked to a elevated level of Na as both quantities are often reciprocal. Among the three varieties, the highest Mg, P and Ca content was observed in Sugarloaf pineapple fruit juice, as compared to that of the MD-2 and Smooth Cayenne pineapple juice.

From the study, to increase the potassium, phosphorus, calcium and magnesium, which are physiologically essential nutrient (Savant *et al.*, 1999), in MD 2 pineapple juice, the processor should use overmatured pineapples harvested in the afternoon and keep in the ambient prior to processing

5.2.1 Moisture Content

The study conducted indicated that Smooth cayenne had relatively higher moisture content than Sugarloaf and MD-2 pineapple variety. As regards the stage of maturity, unmatured fruit had higher moisture content compared to the matured and overmatured fruits. This was not in agreement with studies by Appiah *et al.*, (2011), which indicated that overmatured fruits had higher moisture content.

This gradual increase in the moisture content of the pineapple juice during maturity could be attributed to the loss of moisture from the peels to the pulp. The increase in moisture during maturity allows fruit solutes, usually sugars, to dissolve inducing sweetness

5.2.2 Ash Content

In the study, it was observed that the ash content was not influenced by the time of harvest (Appendices 1O, 2O, and 3O) among the pineapple varieties. However, from (Appendix 2O), maturity stage had a significant influence on ash content of Smooth cayenne pineapple variety, while storage condition had a significant influence on MD-2 pineapple juice (Appendix 3O). It was observed that there was slightly increased with an increase in storage time.

Ash content of varieties of pineapple was found to be in the range of, 0.11 to 0.56% (Sugarloaf), 0.13 to 0.43% (Smooth cayenne) and 0.23 to 0.62% (MD-2) among treatments. These values of ash content (0.23% to 0.50%) are quite similar to that of the experimental variety from the present study (Das and Medhi, 1996)

5.3 Sensory Evaluation of Pineapple Juice

One of the most significant variables for the purchase of a juice item is colour. Juice from Smooth Cayenne was rated to have had the best colour according the panellists (7.5) (Table 9). The colour of juice from overmatured (OMA) was the most preferred by the panellists. This may probably be that the colour of the overmatured fruits was more appealing than the unmatured and matured since consumers will not appreciate pineapple juice that deviates from the natural pineapple juice colour.

During maturation, the aroma of fruits improved (Bender *et al.*, 2000), and that is why the aroma of juice made from matured fruits was generally preferred to unmatured fruits through a sensory evaluation panel. Although, the study recorded that, control had the best aroma (8.5), which was not significantly different from treatment (MMR and OAR) of MD-2. The aromas come from volatile compounds that have been synthetically developed during fruit maturation, and can contain aldehydes, alcohols, esters, lactones, terpens and sulphurs (Kader, 2008). Generally, the overmatured fruits had better aroma values with MD-2 matured having the best value (7.1) as indicated in Table 10.

Taste score of pineapple juice was recorded to be (8.0) in the Sugarloaf pineapple fruit (Table 8). Juice from matured and overmatured Sugarloaf pineapple was most preferred compared to unmatured pineapple fruit (Table 8). The panellists, however, did not like the taste of juice from the matured due to their sourness (acidic). Generally, the juice from Sugarloaf matured was most preferred compared to both Smooth Cayenne and MD-2 overmatured. This may be due to the high TSS of the sugar loaf variety to the MD2 and smooth cayenne. The characteristic of taste is determined by the content of sugar and organic acids (Kader, 2008).

For overall acceptability, sensory panels generally preferred juice produced from Sugarloaf (8.1) to the MD-2 and Sugarloaf varieties. Juice produced from overmatured fruits was most accepted by the sensory panel. This may be due to the less acidic content of the overmatured fruits since maturation is known to reduce acid levels in fruits (Lacey *et al.*, 2009).

5.4 Microbial Quality of Pineapple Juice

In this study, it was observed that Total plate count was recorded to be high in Sugarloaf pineapple juice while, Total plate count contamination was minimal in MD-2 pineapple juice. The low total plate counts for ambient temperature MD-

2 pineapple juice samples could probably be due to reduced pH resulting from bacterial metabolic activities (Kaddumukasa *et al.*, 2017).

Also, there was some level of yeast and mould contamination among all the pineapple juice. It was observed that Sugarloaf pineapple juice recorded the highest mean of yeast and mould count (4.180 cfu/ml).

In general, the microbial quality of the pineapple juice from all three pineapple varieties was below the limit of microbial shelf life for juice, which is 6 log cfu/ml (Chia *et al.*, 2012).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

The study was conducted to assess the impact of some preharvest and postharvest factors on pineapple juice quality and safety of the sugarloaf, smooth Cayenne and MD2 pineapple varieties. There were variations in the physicochemical characteristics of the fruit juice from the different pineapple varieties used. The main changes in fruit composition such as physicochemical properties are usually associated with the maturation process and storage temperature. The result of this work shows the following:

1. Overmatured sugarloaf was observed to have higher total antioxidant and flavoinoid content, when fruits were harvested in the afternoon and refrigerated. Also, harvesting of MD-2 pineaple fruit in the morning had an increase in total antioxidant content. In addition, smooth cayenne pineapple harvested in the morning and stored in ambient condition also had significantly higher total flavonoid content in juice content. Also, overmatured sugarloaf pineapple fruit was observed to have significantly higher Vitamin C content. Although, both afternoon and evening harvesting time of sugarloaf pineapple were also observed to have detrimental effect on Vitamin C content. Refrigeration of Smooth cayenne pineapple fruit resulted in a signifincat decrease in Vitamin C content. The total soluble solid and titratable acidity content in overmatured sugarloaf, smooth cayenne and MD 2 pineapple fruit juice were observed to be

significantly higher. Also, evening time of harvest of MD-2 pinenapple fruit was observed to have significantly increase TSS content in some extent.

2. In the present study, there was significant differences in mineral content among the pineapple varieties. The mineral composition of Na and P were observed to be higher in MD-2 pineapple juice, although, low K content was observed among treatments in MD2 pineapple juice. In addition, among the three varieties, the highest Mg, P and Ca content was observed in Sugarloaf pineapple fruit juice, as compared to that of the MD-2 and Smooth Cayenne pineapple juice.
3. The study indicated that the maturity stage of pineapple fruit has sensory implications on juice produced. Sensory attributes of the overmatured pineapple juice were more appealing to the panellists compared to both the unmatured and matured pineapple fruit. Juice from overmatured sugarloaf was most preferred compared to both smooth cayenne overmatured and MD-2 overmatured. For overall acceptability, the juice from sugarloaf overmatured was the most accepted by the sensory panel.
4. The microbial quality of the pineapple juices was below the limit of microbial shelf life for juice. Total plate count contamination was minimal in MD-2 pineapple juice at the storage temperature of 37 ^{o}C after 2 days. This could be due to the high acid content of the MD-2 pineapple juice. Sugarloaf pineapple juice had a relatively higher mean of yeast and mould count (4.180 cfu/ml) at a storage temperature of 25 ^{o}C after 7 days. Juice samples refrigerated at 5 ^{o}C was

found to be the best, since there was no detection of total plate count and yeast mould, after 7 days storage.

6.2 RECOMMENDATION

In light of the results of this study, the following recommendations are made with some suggestions for further study.

1. Juice produced from overmatured pineapples harvested in the morning were found to have good physicochemical properties, however, if a producer wants to harvest in the afternoon, the fruits should be refrigerated
2. Juice should be pasteurized to see its effect on the quality of the juice produced.
3. Quality of composite juice prepared from the various varieties of pineapple at different maturity stages should be determined.

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APPENDICES

1. ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Physicochemical properties of Sugarloaf pineapple

Appendix 1A: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Antioxidant Capacity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	1503.0	751.49	10.34	0.000
Time of harvest	2	6130.2	3065.09	42.16	0.000
Storage condition	1	2486.5	2486.48	34.20	0.000
Maturity stage*Time of harvest	4	1980.9	495.24	6.81	0.000
Maturity stage*Storage condition	2	850.4	425.20	5.85	0.006
Time of harvest*Storage condition	2	578.6	289.31	3.98	0.027
Maturity stage*Time of harv.*Storage cond.	4	8828.8	2207.20	30.36	0.000
Total	53	24975.7			

Appendix 1B: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Flavonoids

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	3.6330	1.81648	48.92	0.000
Time of harvest	2	11.2425	5.62123	151.38	0.000
Storage condition	1	0.0000	0.00004	0.00	0.975
Maturity stage*Time of harv	4	24.5341	6.13354	165.18	0.000
Maturity stage*Storage condition	2	3.7261	1.86304	50.17	0.000
Time of harv.*Storage condition	2	13.7531	6.87653	185.19	0.000
Maturity stage*Time of harv.*Storage cond	4	4.3451	1.08627	29.25	0.000
Total	53	62.5706			

Appendix 1C: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Phenol

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	139.02	69.512	3.69	0.035
Time of harvest	2	579.04	289.521	15.36	0.000
Storage condition	1	382.48	382.478	20.29	0.000
Maturity stage*Time of harv	4	382.44	95.611	5.07	0.002
Maturity stage*Storage condition	2	120.25	60.127	3.19	0.053
Time of harv.*Storage condition	2	0.64	0.320	0.02	0.983
Maturity stage*Time of harv.*Storage cond	4	902.83	225.707	11.97	0.000
Total	53	3185.25			

Appendix 1D: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Vitamin C

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	22.320	11.1601	282.84	0.000
Time of harvest	2	61.599	30.7995	780.59	0.000
Storage condition	1	16.336	16.3361	414.03	0.000
Maturity stage*Time of harv	4	53.525	13.3813	339.14	0.000
Maturity stage*Storage condition	2	14.775	7.3875	187.23	0.000
Time of harv.*Storage condition	2	85.105	42.5526	1078.47	0.000
Maturity stage*Time of harv.*Storage cond	4	48.605	12.1511	307.96	0.000
Total	53	303.686			

Appendix 1 E: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on pH

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.42259	0.211296	71.31	0.000
Time of harvest	2	0.05481	0.027407	9.25	0.001
Storage condition	1	0.06000	0.060000	20.25	0.000
Maturity stage*Time of harv	4	0.31852	0.079630	26.87	0.000
Maturity stage*Storage condition	2	0.20111	0.100556	33.94	0.000
Time of harv.*Storage condition	2	0.03111	0.015556	5.25	0.010
Maturity stage*Time of harv.*Storage cond	4	0.21111	0.052778	17.81	0.000
Total	53	1.40593			

Appendix 1 F: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on TSS

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	78.678	39.3391	31.54	0.000
Time of harvest	2	3.360	1.6802	1.35	0.273
Storage condition	1	6.827	6.8267	5.47	0.025
Maturity stage*Time of harv	4	25.381	6.3452	5.09	0.002
Maturity stage*Storage condition	2	5.763	2.8817	2.31	0.114
Time of harv.*Storage condition	2	1.921	0.9606	0.77	0.470
Maturity stage*Time of harv.*Storage cond	4	5.622	1.4056	1.13	0.359
Total	53	172.453			

Appendix 1 G: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total titratable acidity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.00111	0.000557	0.02	0.980
Time of harvest	2	0.04195	0.020974	0.75	0.482
Storage condition	1	0.08725	0.087253	3.10	0.087
Maturity stage*Time of harv	4	0.04764	0.011909	0.42	0.791
Maturity stage*Storage condition	2	0.16493	0.082467	2.93	0.066
Time of harv.*Storage condition	2	0.06422	0.032108	1.14	0.331
Maturity stage*Time of harv.*Storage cond	4	0.09883	0.024707	0.88	0.487
Total	53	1.51864			

Appendix 1 H: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Moisture %

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	125.453	62.7265	5.00	0.012
Time of harvest	2	89.176	44.5881	3.55	0.039
Storage condition	1	85.298	85.2977	6.80	0.013
Maturity stage*Time of harv	4	20.400	5.1000	0.41	0.803
Maturity stage*Storage condition	2	1.341	0.6706	0.05	0.948
Time of harv.*Storage condition	2	75.130	37.5648	2.99	0.063
Maturity stage*Time of harv.*Storage cond	4	58.745	14.6864	1.17	0.340
Total	53	907.186			

Appendix 1 I: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Ash %

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.00758	0.003790	0.13	0.881
Time of harvest	2	0.11866	0.059332	2.00	0.150
torage condition	1	0.03152	0.031517	1.06	0.310
Maturity stage*Time of harv	4	0.30806	0.077016	2.59	0.053
Maturity stage*Storage condition	2	0.03398	0.016989	0.57	0.570
Time of harv.*Storage condition	2	0.03975	0.019876	0.67	0.518
Maturity stage*Time of harv.*Storage cond	4	0.10148	0.025371	0.85	0.501
Total	53	1.71056			

2. ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Physicochemical properties of Smooth cayenne pineapple

Appendix 2A: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Antioxidant Capacity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	865.2	432.61	7.48	0.002
Time of harvest	2	734.2	367.11	6.35	0.004
Storage condition	1	169.7	169.65	2.93	0.095
Maturity stage*Time of harv	4	1747.1	436.76	7.55	0.000
Maturity stage*Storage condition	2	4905.8	2452.89	42.40	0.000
Time of harv.*Storage condition	2	719.0	359.50	6.21	0.005
Maturity stage*Time of harv.*Storage cond	4	8922.1	2230.52	38.56	0.000
Total	53	20145.6			

Appendix 2 B: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Flavonoids

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	1.052	0.5259	0.99	0.380
Time of harvest	2	17.092	8.5460	16.13	0.000
torage condition	1	16.674	16.6738	31.48	0.000
Maturity stage*Time of harv	4	19.442	4.8605	9.18	0.000
Maturity stage*Storage condition	2	2.567	1.2835	2.42	0.103
Time of harv.*Storage condition	2	23.251	11.6256	21.95	0.000
Maturity stage*Time of harv.*Storage cond	4	32.858	8.2145	15.51	0.000
Total	53	132.003			

Appendix 2 C: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Phenols

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	186.81	93.403	12.27	0.000
Time of harvest	2	162.87	81.437	10.70	0.000
Storage condition	1	28.21	28.208	3.71	0.062
Maturity stage*Time of harv	4	579.72	144.930	19.04	0.000
Maturity stage*Storage condition	2	757.66	378.831	49.77	0.000
Time of harv.*Storage condition	2	132.60	66.302	8.71	0.001
Maturity stage*Time of harv.*Storage cond	4	1625.91	406.478	53.41	0.000
Total	53	3747.78			

Appendix 2 D: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Vitamin C

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	1.676	0.8381	16.92	0.000
Time of harvest	2	1.473	0.7364	14.87	0.000
Storage condition	1	14.213	14.2132	286.93	0.000
laturity stage*Time of harv	4	18.107	4.5268	91.39	0.000
Maturity stage*Storage condition	2	7.670	3.8349	77.42	0.000
Time of harv.*Storage condition	2	27.504	13.7519	277.62	0.000
Maturity stage*Time of harv.*Storage cond	4	17.227	4.3067	86.94	0.000
Total	53	89.653			

Appendix 2 E: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on pH

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.024815	0.012407	4.19	0.023
Time of harvest	2	0.200370	0.100185	33.81	0.000
Storage condition	1	0.001667	0.001667	0.56	0.458
Maturity stage*Time of harv	4	0.025185	0.006296	2.12	0.098
Maturity stage*Storage condition	2	0.107778	0.053889	18.19	0.000
Time of harv.*Storage condition	2	0.083333	0.041667	14.06	0.000
Maturity stage*Time of harv.*Storage cond	4	0.255556	0.063889	21.56	0.000
Total	53	0.805370			

Appendix 2 F: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on TSS

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	21.631	10.8156	6.73	0.003
Time of harvest	2	16.734	8.3672	5.21	0.010
Storage condition	1	5.289	5.2891	3.29	0.078
Maturity stage*Time of harv	4	18.404	4.6011	2.87	0.037
Maturity stage*Storage condition	2	1.877	0.9385	0.58	0.563
Time of harv.*Storage condition	2	5.225	2.6124	1.63	0.211
Maturity stage*Time of harv.*Storage cond	4	4.274	1.0685	0.67	0.620
Total	53	131.248			

Appendix 2 G: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Titratable Acidity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.10723	0.053615	2.52	0.094
'ime of harvest	2	0.09394	0.046968	2.21	0.124
Storage condition	1	0.00044	0.000438	0.02	0.887
Maturity stage*Time of harv	4	0.31619	0.079047	3.72	0.012
Maturity stage*Storage condition	2	0.33537	0.167686	7.89	0.001
Time of harv.*Storage condition	2	0.25752	0.128760	6.06	0.005
Maturity stage*Time of harv.*Storage cond	4	0.21808	0.054520	2.57	0.055
Total	53	2.09345			

Appendix 2 H: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Moisture %

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	68.436	34.2178	16.01	0.000
Time of harvest	2	14.642	7.3208	3.43	0.043
Storage condition	1	31.423	31.4229	14.70	0.000
Maturity stage*Time of harv	4	5.191	1.2978	0.61	0.660
Maturity stage*Storage condition	2	8.401	4.2005	1.97	0.155
Time of harv.*Storage condition	2	1.006	0.5030	0.24	0.792
Maturity stage*Time of harv.*Storage cond	4	14.835	3.7087	1.74	0.164
Total	53	220.880			

Appendix 2 I: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Ash %

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.084617	0.042308	4.50	0.018
Time of harvest	2	0.025790	0.012895	1.37	0.266
torage condition	1	0.000970	0.000970	0.10	0.750
Maturity stage*Time of harv	4	0.051067	0.012767	1.36	0.267
Maturity stage*Storage condition	2	0.000443	0.000222	0.02	0.977
Time of harv.*Storage condition	2	0.103391	0.051696	5.50	0.008
Maturity stage*Time of harv.*Storage cond	4	0.048125	0.012031	1.28	0.296
Total	53	0.652617			

3. ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Physicochemical properties of Sugarloaf pineapple

Appendix 3A: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Antioxidant Capacity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	23232	11615.9	846.81	0.000
Time of harvest	2	5821	2910.3	212.16	0.000
Storage condition	1	66957	66957.4	4881.27	0.000
Maturity stage*Time of harv	4	139935	34983.7	2550.35	0.000
Maturity stage*Storage condition	2	34711	17355.6	1265.24	0.000
Time of harv.*Storage condition	2	16717	8358.3	609.33	0.000
Maturity stage*Time of harv.*Storage cond	4	51975	12993.8	947.26	0.000
Total	53	339842			

Appendix 3 B: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Flavonoids

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	1.8523	0.92615	11.01	0.000
Time of harvest	2	13.3434	6.67171	79.28	0.000
Storage condition	1	0.6469	0.64692	7.69	0.009
Maturity stage*Time of harv	4	18.5425	4.63562	55.08	0.000
Maturity stage*Storage condition	2	1.8624	0.93120	11.07	0.000
Time of harv.*Storage condition	2	10.4376	5.21881	62.01	0.000
Maturity stage*Time of harv.*Storage cond	4	7.2661	1.81653	21.59	0.000
Total	53	56.9809			

Appendix 3 C: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Phenol

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	27.15	13.58	1.26	0.296
Time of harvest	2	387.86	193.93	18.00	0.000
Storage condition	1	147.59	147.59	13.70	0.001
Maturity stage*Time of harv	4	2386.52	596.63	55.38	0.000
Maturity stage*Storage condition	2	143.05	71.52	6.64	0.004
Time of harv.*Storage condition	2	682.86	341.43	31.69	0.000
Maturity stage*Time of harv.*Storage cond	4	641.01	160.25	14.87	0.000
Total	53	4803.89			

Appendix 3 D: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Vitamin C

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	435.3	217.649	0.71	0.000
Time of harvest	2	134.7	67.340	0.22	0.000
Storage condition	1	38.1	38.138	0.12	0.000
Maturity stage*Time of harv	4	598.1	149.534	0.49	0.000
Maturity stage*Storage condition	2	247.3	123.670	0.40	0.000
Time of harv.*Storage condition	2	879.0	439.482	1.44	0.000
Maturity stage*Time of harv.*Storage cond	4	33.7	8.429	0.03	0.000
Total	53	13360.7			

Appendix 3 E: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on pH

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.038681	0.019341	1492.00	0.000
Time of harvest	2	0.011026	0.005513	425.29	0.000
Storage condition	1	0.027113	0.027113	2091.57	0.000
Maturity stage*Time of harv	4	0.099030	0.024757	1909.86	0.000
Maturity stage*Storage condition	2	0.092904	0.046452	3583.43	0.000
Time of harv.*Storage condition	2	0.021915	0.010957	845.29	0.000
Maturity stage*Time of harv.*Storage cond	4	0.068185	0.017046	1315.00	0.000
Total	53	0.359320			

Appendix 3 F: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Soluble Solids

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	62.848	31.4239	118.09	0.000
Time of harvest	2	4.463	2.2317	8.39	0.001
torage condition	1	8.245	8.2446	30.98	0.000
Maturity stage*Time of harv	4	3.032	0.7581	2.85	0.038
Maturity stage*Storage condition	2	6.723	3.3613	12.63	0.000
Time of harv.*Storage condition	2	3.767	1.8835	7.08	0.003
Maturity stage*Time of harv.*Storage cond	4	10.851	2.7127	10.19	0.000
Total	53	109.508			

Appendix 3 G: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Total Titratable Acidity

Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.23519	0.117597	15.79	0.000
Time of harvest	2	0.02452	0.012260	1.65	0.207
Storage condition	1	0.01974	0.019742	2.65	0.112
Maturity stage*Time of harv	4	0.14081	0.035203	4.73	0.004
Maturity stage*Storage condition	2	0.02453	0.012263	1.65	0.207
Time of harv.*Storage condition	2	0.04786	0.023929	3.21	0.052
Maturity stage*Time of harv.*Storage cond	4	0.15029	0.037573	5.04	0.002
Total	53	0.91106			

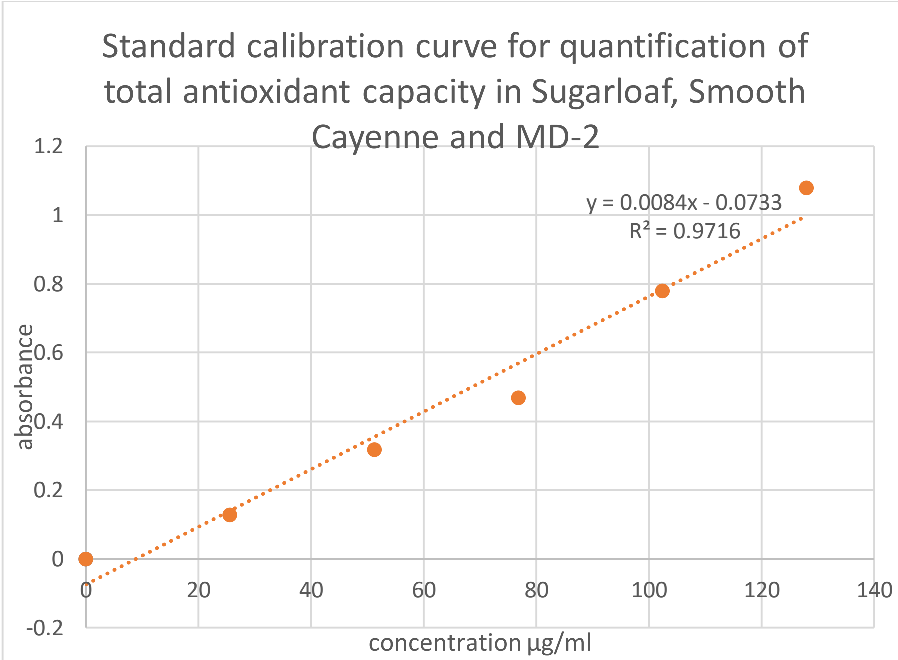
Appendix 3 H: ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Moisture %

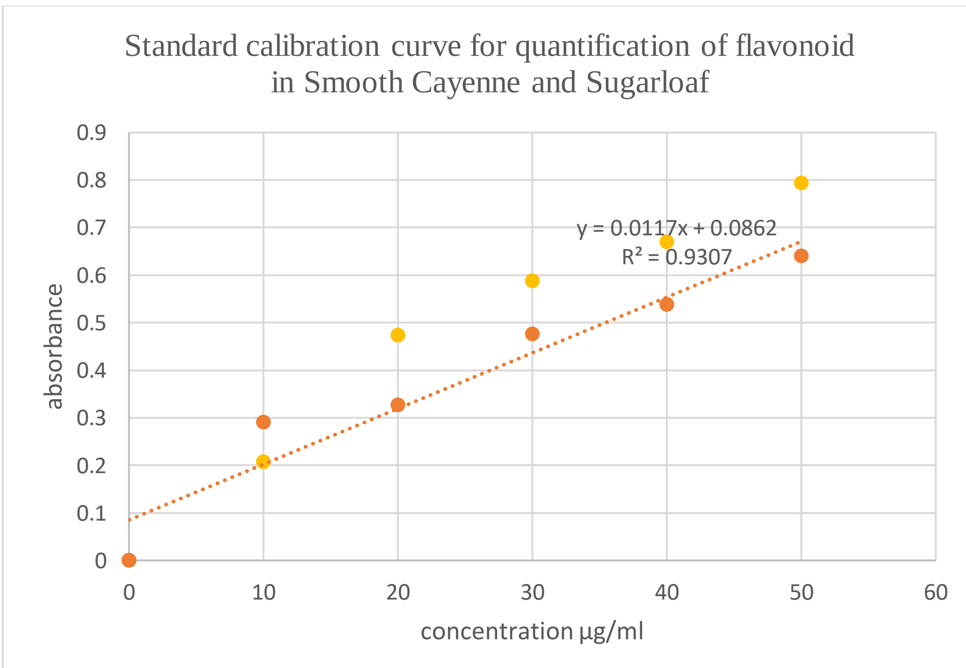
Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	19.934	9.967	3.58	0.038
Time of harvest	2	19.358	9.679	3.48	0.041
torage condition	1	40.444	40.444	14.55	0.001
Maturity stage*Time of harv	4	18.372	4.593	1.65	0.183
Maturity stage*Storage condition	2	4.518	2.259	0.81	0.452
Time of harv.*Storage condition	2	7.845	3.922	1.41	0.257
Maturity stage*Time of harv.*Storage cond	4	20.095	5.024	1.81	0.149
Total	53	230.667			

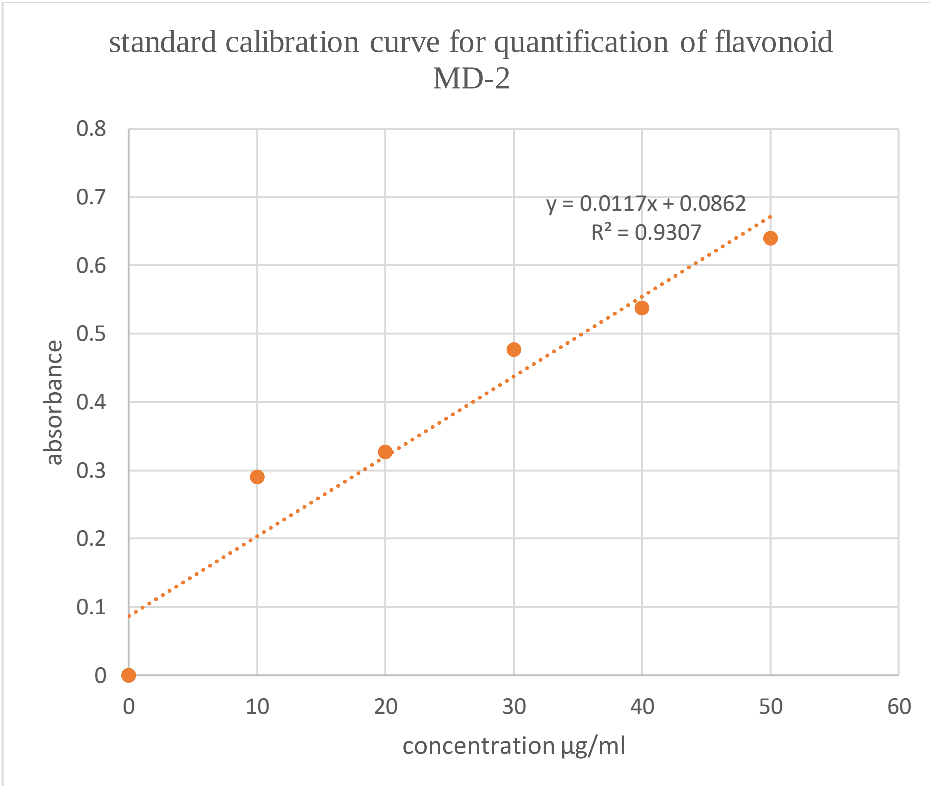
Appendix 3 I ANOVA of the Effects of Maturity Stage, Time of Harvest and Storage on Ash %

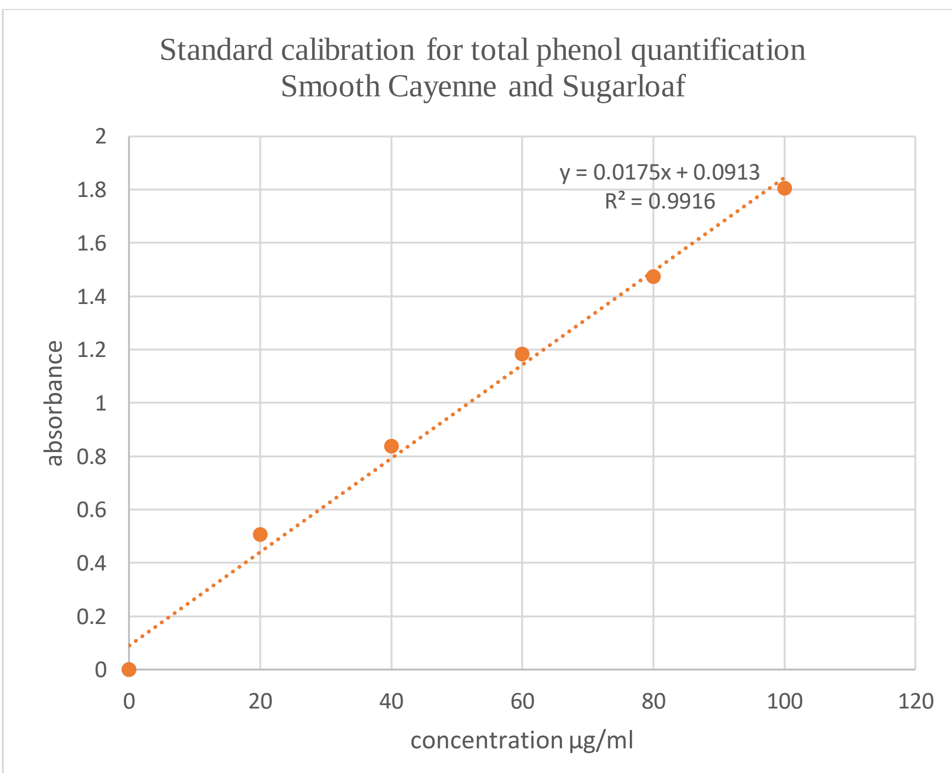
Source	DF	Adj SS	MS	F-Value	P-Value
Maturity stage	2	0.03884	0.019421	1.33	0.277
Time of harvest	2	0.03830	0.019152	1.31	0.282
Storage condition	1	0.11512	0.115117	7.88	0.008
Maturity stage*Time of harv	4	0.04400	0.010999	0.75	0.563
Maturity stage*Storage condition	2	0.01591	0.007954	0.54	0.585
Time of harv.*Storage condition	2	0.01455	0.007277	0.50	0.612
Maturity stage*Time of harv.*Storage cond	4	0.27615	0.069038	4.73	0.004
Total	53	1.06885			

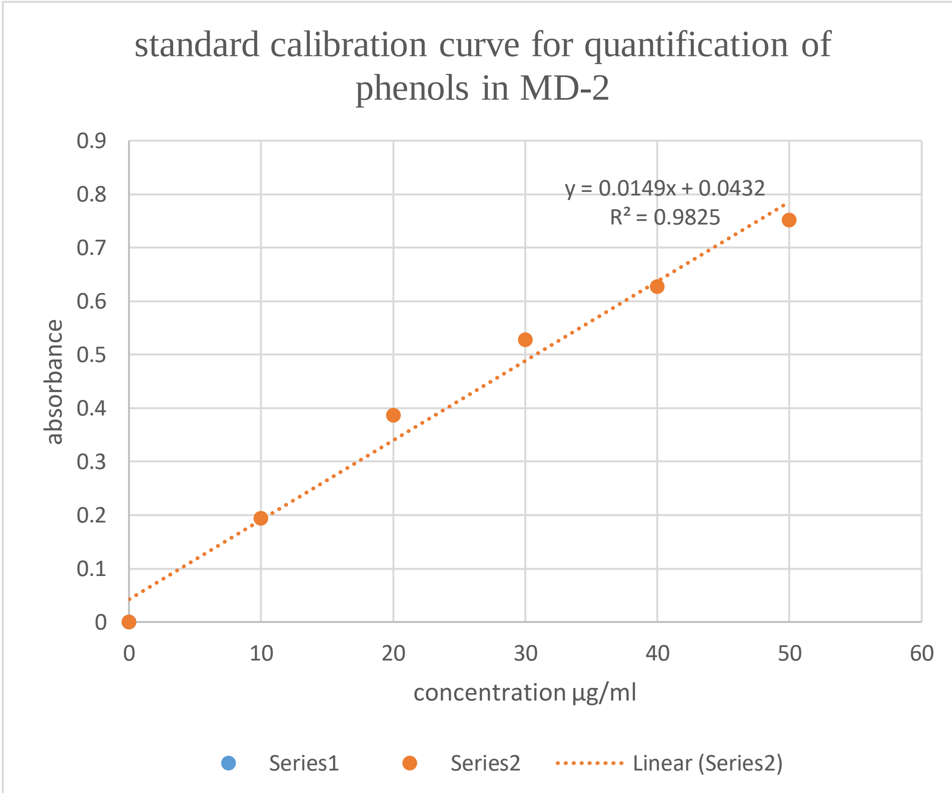
Appendix 4: Standard Curve for Physicohemical Properties






standard calibration curve for quantification of flavonoid MD-2
y = 0.0117x + 0.0862
R² = 0.9307
absorbance
concentration µg/ml
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
10
20
30
40
50
60


Standard calibration for total phenol quantification Smooth Cayenne and Sugarloaf
y = 0.0175x + 0.0913
R² = 0.9916
absorbance
concentration µg/ml
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
0
20
40
60
80
100
120


standard calibration curve for quantification of phenols in MD-2
y = 0.0149x + 0.0432
R² = 0.9825
absorbance
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
concentration µg/ml
Series1
Series2
Linear (Series2)

Appendix 5: Treatment combination of Matutiy stage, Time of harvest and Storage condition of pineapple varieties.

Appendice A: Experimental design of variable combination for MD2 pineapple variety (No Reps)

Sample ID	Maturity stage	Time of harvest	Storage condition
UMA	Unmatured	Morning	Ambient
MMA	Matured	Morning	Ambient
OMA	Overmatured	Morning	Ambient
UAA	Unmatured	Afternoon	Ambient
MAA	Matured	Afternoon	Ambient
OAA	Overmatured	Afternoon	Ambient
UEA	Unmatured	Evening	Ambient
MEA	Matured	Evening	Ambient
OEA	Overmatured	Evening	Ambient
UMR	Unmatured	Morning	Refrigerated
MMR	Matured	Morning	Refrigerated
OMR	Overmatured	Morning	Refrigerated
UAR	Unmatured	Afternoon	Refrigerated
MAR	Matured	Afternoon	Refrigerated
OAR	Overmatured	Afternoon	Refrigerated
UER	Unmatured	Evening	Refrigerated
MER	Matured	Evening	Refrigerated
OER	Overmatured	Evening	Refrigerated

Appendix 6: Sensory Evaluation Form

Apendice A: Sensory Evaluation Form

REFERENCE SCALE	MEANING
1	Dislike Extremely
2	Dislike Very Much
3	Dislike Moderately
4	Dislike Slightly
5	Neither Like Or Dislike
6	Like Slightly
7	Like Moderately
8	Like Very Much
9	Like Extremely

Apendice B: Sensory Evaluation Form

SENSORY EVALUATION PARAMETER **1**	**1**	**2**	**3**	**4**	**5**		**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Colour (*How attractive the sample appears to you*)														
Aroma (*product smell or fragrance while in the mouth*)														
Taste (*Sensation felt while the Sample is In your Mouth*)														
Aftertaste (*Persistence of the taste of the sample after swallowing*)														
Overall acceptability (*How acceptable the product is to you*														