Quality Parameters of Banana Fruit As Influenced by Traditional Ripening Techniques

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Abstract
Fruit ripening involve several physiological, biochemical, and molecular processes resulting in tissue softening, changes in sugar content, reduction in acidity, pigments and flavour components. Fruit ripening process can be stimulated by applying some traditional ripening agents. The study was therefore carried out to assess the effects of some traditional induced ripening techniques on the physicochemical, proximate, mineral and sensory properties of banana fruits. Matured green banana bunch were collected and subjected to four different traditional ripening methods, namely calcium carbide, potash, black polythene bag and hot water and compared with natural ripened banana fruit. Ripening duration, physicochemical, proximate, mineral, and sensory properties of the banana samples were assessed using standard method of analysis. Result of physicochemical parameters indicated that the total soluble solid (TSS) was lowest in the sample ripened with ca carbide (11.53% Brix) while the control sample with (17.83% Brix) had the highest. Values obtained for weight loss and pH did not show any significant difference. Result from proximate composition indicated that the control sample recorded the highest values in fibre (1.33%), protein (3.58%), fat (1.31%), and energy (132.15 Kcal/100g) content. The addition of traditional ripening agent positively impacted on the calcium content and negatively on the vitamin C content as well as sensory parameters such as taste, firmness, appearance aroma and over acceptability of banana fruit. The study indicates that naturally ripened bananas was superior in vitamin C and sensory characteristics compared to treated banana while Ca carbide was the most effective of ripening agent in terms of ripening duration.

Keywords: *Banana, Ripening techniques, Quality parameters, Fruit, Acceptability*

INTRODUCTION

Banana (*Musa* spp.) is a widely cultivated and consumed fruit in the world. It is said to be one of the commonest fruit crops which was cultivated at the beginning of the civilization. Banana is a native to South East Asia and it is grown in over 130 countries in the tropical and subtropical regions of the world. Banana is said to be the fourth largest food crop of the world (Hailu *et al*., 2013). The current annual global production is a little over 120 million metric tons in 2020. Banana is grown predominantly in Latin America (Brazil), India, Philippines while Uganda is the considerably the greatest banana producer in Sub-Saharan Africa followed by Rwanda Ghana Nigeria and Cameroon (Hailu *et al*., 2013; FAO, 2021).

Banana fruit serves as good nutritional sources of carbohydrates, minerals such as potassium and vitamins (Cejpek 2012). Banana fruit contains phytochemical and bioactive compounds which have been reported to provide additive and synergistic combinations of anti-oxidative potential and chemopreventive capabilities. They also exert some health beneficial effects to human body and helping in protecting the body against oxidative stress. Such compounds including ascorbic acid, phenolics, carotenoids, alkaloids, tannins, saponins, steroids, biogenic amines, phytosterols, among others are highly desirable in diet (Singh *et al*., 2018; Ketron and Osheroff, 2014). The incorporation of banana pulp in various food products is believed to add value to such products since banana is loaded with nutrients that are beneficial to human health.

The banana fruit can be consumed cooked, processed into flour or fermented for the production of beverages such as banana juice, beer etc. The fruit is inconsistent in size, colour, and firmness but is generally elongated and bowed, with flexible soft tissue which is high in starch covered with a skin, which may be red, yellow, green, brown, or purple while ripe. Being a major fruit crop, it has an international commercial importance, however, its short shelf life seriously limits the marketing of the fruit, where extending banana shelf life could be a considerable commercially benefit to both exporters and retailers (Varit and Songsin, 2011). The quality of banana fruit rapidly deteriorate when fully ripened. Fruit ripening is a natural process involving combination of series of molecular activities resulting in physiological, biochemical changes in which fruit gradually become sweet, colored, soft and palatable (Bauzayen *et al*., 2010). Ripening is characterized by an irreversible changes in the constituents of banana fruit involving conversion of starch to sugar, reduction of sourness and increase in the sweetness due to decrease in acidity and increase in sugars with a corresponding development of aroma volatiles, flavour compounds, phenolic compounds, and organic acids (Maduwanthi and Marapana, 2019; Saddiqui and Marapana, 2019). The irreversible changes in color corresponding the ripening process of fruit is as a consequence of unmasking of pigments by enzymatic degradation of chlorophyll, synthesis of various types of anthocyanins and their deposition in vacuoles, and the accumulation of carotenoids. Production of complex mixture of volatile compounds, such as ocimene and myrcene, and degradation of the bitter components involving different categories of plant components such as alkaloid and sesquiterpene which are connected essentially by their bitter taste as well as flavonoids, tannins, and other related compounds which enhance the flavor and aroma of the fruit. Sweetness increases as a result of acceleration of gluconeogenesis; a metabolic pathway that generates glucose, enzymatic degradation and hydrolysis of polysaccharides, decreased acidity, and accumulation of sugars and organic acids. Furthermore, textural changes resulting in the softening of fruits occur due to enzyme-regulated alteration in the pectin structure and composition of the cell wall (Islam *et al*., 2016; Tucker and Grierson 1987).Through the above changes, fruit becomes ripe with attractive and distinctive properties making it sweet, coloured, soft, and palatable. Fruit ripening of fruit is closely associated with ethylene gas, a phytohormone that can trigger initiation of ripening and senescence. Based on biochemically controlled mechanisms resulting in fruit ripening, fruits can be classified into climacteric or non-climacteric fruits. Banana is a climacteric fruit (Maduwanthi and Marapana, 2019). Ripening of fruits can be instigated artificially through the use of several natural/chemical agents and sometimes applied recurrently on fruits to hasten ripening process (Goonantilake, 2008; Hakim *et al*., 2012). Artificial ripening is carried out to enhance quick and uniform ripening and with banana being classified into climacteric family it is usually harvested at the pre-climacteric stage and for commercial reasons it is artificially ripened. Artificial ripening enables traders to minimize losses during transportations and as well as timely availability of the product at desired ripening form. Different fruit ripening methods can be employed to hasten the ripening fruits artificially as well as to give fruits the desired color and taste at the shortest possible time. Currently, the application of artificial fruit ripening methods is becoming widespread and some of these methods being mostly applied for large scale purposes to make the fruits available to customers during off-season have studied by different researchers globally (Tucker and Grierson 1987; Rahman *et al*., 2008). Some of these chemicals include; calcium carbide, potash, polythene bag, hot water, methanol, kerosene, smoke fumes among others. Most of these studies have focused on the immediate and indirect health consequences resulting from the application of chemicals and other ripening inducing or enhancing agents and their contaminants which require qualitative and quantitative analysis of their toxicity index and their effects on fruit quality and safety. However, the effects of these chemically induced ripening agents on the nutrient content of fruits are yet to be fully understood (Islam *et al*., 2016). The study aimed at assessing the effects of artificial induced ripening techniques on the Physicochemical, proximate and sensory properties of banana fruit.

MATERIALS AND METHODS

Source of Raw Materials

Mature green banana (unripe) *musa sp.* locally known as Four corner banana was purchased from Mbiokporo market in Nsit-Ibom local government area of Akwa-Ibom state. All chemical reagents used in this study were of analytical grade and the work was carried out at the Food processing laboratory, Department of Food Science and Technology, University of Uyo.

Sample Preparation and Treatments

The unripe and matured banana fruits were carefully separated from the bunch, washed with clean water to remove dirt and gums on the banana peel. The unripe banana was divided into 5 samples, each containing 9 fingers of banana of uniform weight. Banana samples were treated with calcium carbide, potash, hot water, stored in polythene bag while the last sample was stored in normal condition (control). A 10g Calcium carbide and Potash powder was packed in thin layer paper, dissolved separately in 20mL of deionized in water and then kept in a container with the fresh unripe banana sample (Foster *et al*., 2003; Islam *et al*., 2018). The other banana sample was dipped in hot water at 65^oC for 30 seconds then place in a container and covered for ripening (Ikhajiagbe *et al*., 2021; Foster *et al*., 2003), while the other sample was wrapped in a black polythene bags, and stored under room condition. Banana sample that served as control was stored at room temperature without the addition of ripening agent (Kaka *et al*., 2018).

Determination of Ripening Duration of Banana Samples

Banana samples treated with different ripening agents and the control samples were stored and monitored every 24 hours and the ripening time (days) were noted and recorded. This was to determine the effectiveness of the different ripening agent in inducing uniform ripening of banana fruit.

Determination of Physicochemical Parameters

Total soluble solids (% Brix)

The total soluble solids of fruit pulp was measured with the help of refractometer and reading was expressed in percentage (%Brix). Refractometer before using was standardized with distilled water and was then adjusted to 0% Brix. 10 grams of pulp tissue was homogenized in 40 ml distilled water in the blender jug, and was then filtered with filter paper. The reading was recorded by pouring two drops of filtrate on the glass prism of the refractometer (AOAC 2010).

Titratable Acidity (%)

Titratable acidity (also known as total acidity) was determined by titrating the pulp concentration against 0.1N Sodium hydroxide (NaOH) using phenolphthalein as indicator until the concentration changed to pink colour, the results were expressed as percentage of malic acid in flesh pulp weight (AOAC 2010).

Pulp pH

Pulp pH was determined in the pulp juice with a digital pH meter. About 10 grams of samples were taken and blended separately into 40 ml distilled water, preparing a concentration. After that, the probe of pH meter was dipped in concentration and readings were recorded (AOAC 2010).

Weight Loss

Banana fruits were weighed before and after placing the samples in storage at an interval five days. The weight was determined using sensitive balance. The percentage of weight loss was calculated using the expression given below (Soomro *et al.*, 2016).

$$\text{Weight loss (\%)} = \frac{\text{Initial weight (g)} - \text{Weight after ripening (g)}}{\text{Intial weight (g)}} \text{X } 100$$

Proximate composition

Proximate composition of ripened fruit pulp was determined according to standard methods of analysis (AOAC 2010). Moisture content determined using the procedure of vacuum oven method, the micro-Kjeldahl method was used to determine protein content, crude fat content was determined by the Soxhlet extraction method, the total ash was determined by incineration of dried sample obtained in muffle furnace at 550^0C for 24hours, crude fiber was obtained using trichloroacetic acid method while carbohydrate content was obtained by difference while the energy values were determined using known energy content per gram of nutrient as a standard for conversion;

The energy value was thus calculated from the formula below; Energy = (g of fat X 9) + (g of protein X 4) + (g of carbohydrate X 4) (AOAC 2010).

Determination of vitamin C

The direct calorimetric method as described by AOAC (2010). will be used to determine the vitamin C content of the samples. It will be based on the extent to which a 2,6-dichlorophenol-indephenol solution is decolourized by ascorbic acid in sample extracts and in standard ascorbic acid. The sample (50g) was blended with an equal weight of 6% HPO_3, and an aliquot of the macerate was made up to 100ml.

Sensory Evaluation

Sensory evaluations of the banana samples were determined according to the method outlined by Ihekoronye and Ngoody (1985) using a twenty-member semi-panelist consisting of staff Food processing Labouratory and some students of Department of Food Science and Technology, University of Uyo Nigeria. The Panelists were either regular or occasional consumers of banana and were not allergic to any food. Banana samples with different treatment were presented in coded white plastic container. Portable water was provided to rinse the mouth between evaluations. Samples were presented randomly. The panelists were instructed to evaluate the coded samples for taste, mouthfeel, colour, texture, aftertaste and overall acceptability. Each sensory attribute was rated on a 9-point Hedonic scale (9 for liked extremely and 1 for disliked extremely).

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Statistical Analysis

All experiments were conducted in triplicate and data obtained were subjected to analysis of Variance (ANOVA) using statistical package for social sciences (SPSS) version 22.0. New Duncan Multiple Range Test (DMRT) was used to compare the differences between treatment means at a significant level ($P<0.05$). Results were expressed as the means with standard deviation of three separate determinations.

RESULTS

Ripening Duration of Ripened Banana Samples

The results of the ripening duration of different banana sample treatments is presented in Figure 1. It showed that banana sample treated with calcium carbide ripened in 3 days which was the most effective ripening agents. This was closely followed with sample treated with hot water (6days), Potash (8days), Polythene (10days) while the control sample took 13 days to fully ripen

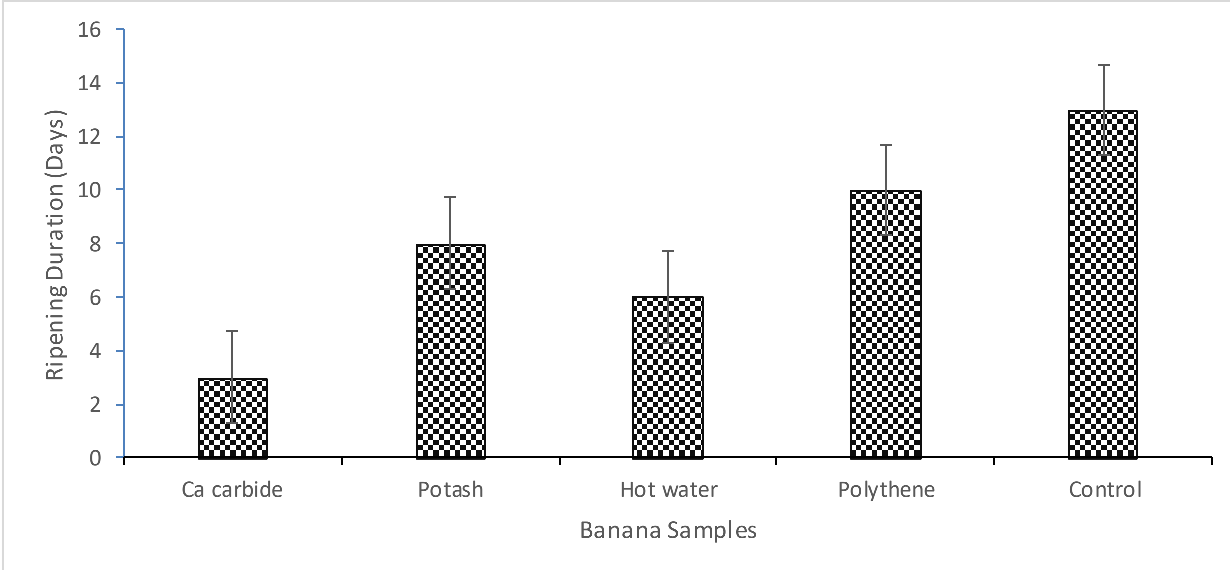

Figure 1: Ripening duration as affected by different treatment methods

Physicochemical Properties of Ripened Banana Samples

The results of the physicochemical properties of ripened banana sample is presented in Table 1. The total suspended solid (TSS) ranged from 9.50 % Brix to 17.83 % Brix. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in polythene ripened banana. The total titratable acidity (TTA) ranged from 0.02% to 0.38%. The highest value was observed in banana ripened with calcium carbide while the lowest value was observed in the untreated banana sample (control). The pH value ranged from 4.94 to 5.49. The highest value was observed in banana ripened with potash while the lowest value was observed in the calcium carbide treated banana sample. The pulp weight loss ranged from 10% to 40%. The highest value was observed for banana ripened using hot water.

Table 1: Physicochemical properties of Ripened Banana Samples.

Parameter	Ca carbide	Potash	Hot water	Polythene	Control
TSS (%Brix)	$11.53^{c}\pm0.15$	$13.60^{b}\pm0.10$	$13.70^{b}\pm0.11$	$9.50^{c}\pm2.87$	$17.83^{a}\pm0.40$
pH	$4.97^{a}\pm0.10$	$5.04^{a}\pm0.10$	$5.00^{a}\pm0.10$	$5.02^{a}\pm0.01$	$5.04^{a}\pm0.18$
Weight loss (%)	$28.87^{a}\pm0.01$	$29.08^{a}\pm0.02$	$28.78^{a}\pm0.01$	$29.48^{a}\pm0.02$	$30.02^{a}\pm0.02$
TTA (%)	$0.38^{a}\pm0.03$	$0.05^{c}\pm0.02$	$0.07^{b}\pm0.02$	$0.06^{c}\pm0.03$	$0.02^{c}\pm0.05$

Values are represented as means ± standard deviation of triplicate (3) replication. Data in the same row bearing different superscript differed significantly ($p<0.05$).

Keys: TSS: Total Suspended Solid TTA: Total Titratable Acidity.

Proximate composition and Energy value of Ripened Banana Samples

The result of the proximate composition and energy value of ripened banana sample is presented in Table 2. The moisture content ranged from 66.28% to 73.55%. The highest moisture content was observed in banana treated with hot water while the lowest value was observed in banana treated with potash. The ash content ranged from 0.99% to 2.68%. The highest value was observed in banana treated with carbide while the lowest value was observed in the untreated banana sample (control). The fibre content ranged from 0.47% to 1.33%. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana ripened in polythene bags. The protein content ranged from 1.69% to 3.56%. Untreated banana sample (control) had the highest protein content while the lowest value was observed in banana ripened with carbide. The fat content ranged from 0.34% to 1.31%. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana treated with hot water. The carbohydrate content ranged from 21.75% to 27.60%. Banana ripened with potash had the highest carbohydrate value while the lowest carbohydrate value was observed in banana treated with hot water. The energy value ranged from 100.52 Kcal/100g to 132.15 Kcal/100g. The highest energy value was observed the untreated banana sample (control) while the lowest value was observed in banana treated with hot water.

Table 2: Proximate composition and Energy value of Ripened Banana Samples

Parameter	Ca carbide	Potash	Hot water	Polythene	Control
MC (%)	$70.26^{c}\pm0.03$	$72.33^{b}\pm0.01$	$73.55^{a}\pm0.01$	$67.76^{d}\pm0.04$	$66.28^{e}\pm0.05$
Ash (%)	$2.67^{a}\pm0.01$	$1.43^{c}\pm0.01$	$1.24^{d}\pm0.01$	$2.04^{b}\pm0.02$	$0.99^{e}\pm0.01$
Fibre (%)	$0.67^{b}\pm0.01$	$0.65^{b}\pm0.01$	$0.52^{c}\pm0.02$	$0.47^{b}\pm0.03$	$1.33^{a}\pm0.02$
Protein (%)	$1.69^{d}\pm0.01$	$1.83^{d}\pm0.02$	$2.52^{c}\pm0.01$	3.01b±0.02	$3.56^{a}\pm0.01$
Fat (%)	$1.24^{b}\pm0.01$	$0.68^{c}\pm0.03$	0.34e±0.02	$0.41^{d}\pm0.04$	$1.31^{a}\pm0.01$
CHO (%)	$23.48^{c}\pm0.03$	$27.60^{a}\pm0.02$	$21.85^{d}\pm0.02$	$21.75^{d}\pm0.02$	$26.53^{b}\pm0.05$
Energy (Kcal/100 g)	$111.60^{c}\pm0.05$	$123.79^{b}\pm0.03$	$100.52^{e}\pm0.02$	$102.67^{d}\pm0.01$	$132.15^{a}\pm0.03$

Values are represented as means ± standard deviation of triplicate (3) replication. Data in the same row bearing different superscript differed significantly ($p<0.05$).

Keys: MC: Moisture Content CHO: Carbohydrate

Mineral Content of Banana samples

The mineral content of banana as influenced by traditional ripening methods is indicated in Table 3 below; The result indicated an increased in calcium content when compared to the control sample. Banana sample treated hot water and polythene indicated a minor reduction in calcium content with no significant difference between them. However, banana sample ripened with potash showed a significant reduction in calcium content. Similarly, samples ripened with hot water, polythene bags and potash caused a reduction in phosphorus content of banana samples when compared to the control sample. Also, all the traditional ripening method used in this study did not significantly affect the magnesium content of banana sample

Table 3: Mineral content of banana samples (mg/100g)

Parameter	Ca carbide	Potash	Hot water	Polythene	Control
Calcium	$271.68^{a}\pm2.15$	$189.17^{c}\pm0.71$	$230.92^{b}\pm2.11$	$238.58^{bc}\pm8.86$	$232.43^{b}\pm5.33$
Phosphorus	$85.51^{a}\pm0.01$	$36.14^{c}\pm0.10$	$50.98^{b}\pm0.02$	$45.74^{d}\pm0.04$	$84.12^{a}\pm0.01$
Magnesium	$6.96^{a}\pm0.03$	$7.02^{a}\pm0.02$	$6.95^{a}\pm0.05$	$7.03^{a}\pm0.02$	$6.98^{a}\pm0.02$

Values are represented as means ± standard deviation of triplicate (3) replication. Data in the same row bearing different superscript differed significantly ($p<0.05$).

Vitamin C content of Ripened Banana Samples

The result of the vitamin C content of ripened banana sample is presented in Figure 2. The vitamin C content ranged from 9.86 mg/100g to 12.88 mg/100g. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in hot water ripened banana.

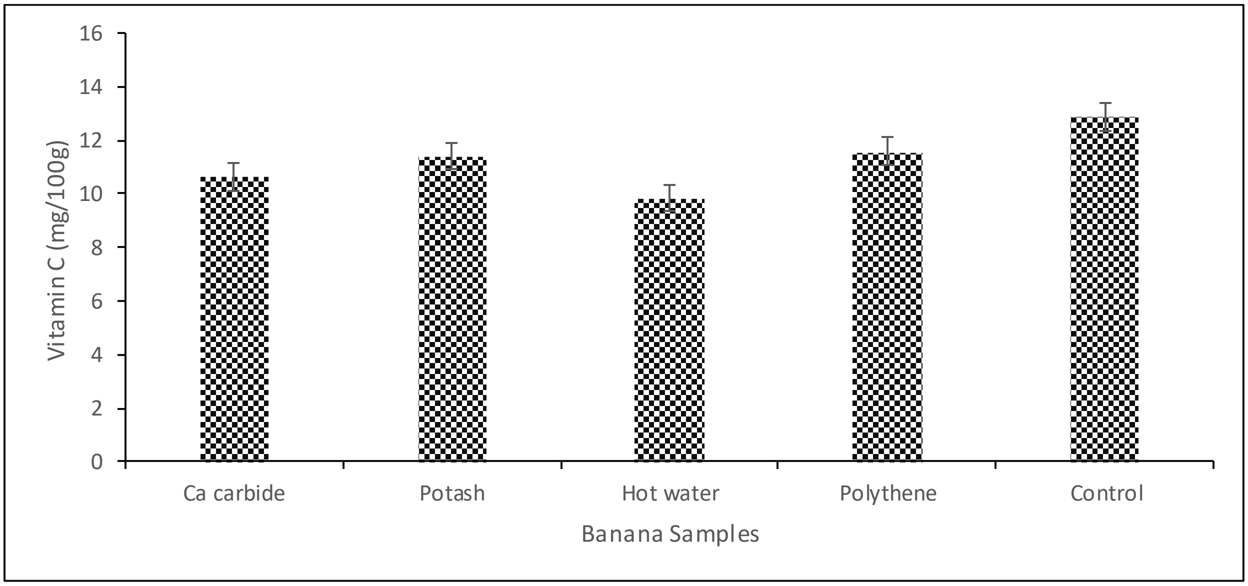

Figure 2: Vitamin C content of banana samples as affected by different treatment methods

Sensory Evaluation of Ripened Banana Samples

The result of the sensory evaluation of ripened banana sample is presented in Table 4. The taste of the ripened banana ranged from 2.95 to 8.00. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana ripened with polythene bag. The firmness ranged from 5.35 to 7.95. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana ripened with polythene bag. The appearance ranged from 5.45 to 7.95. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana treated with hot water. The aroma ranged from 2.85 to 7.85. The highest value was observed in the untreated banana sample (control) while the lowest value was observed for banana treated with hot water. The mouthfeel ranged from 3.00 to 7.90. The untreated banana sample (control) recorded the highest value while the lowest value was recorded for banana treated with hot water. The overall acceptability ranged from 3.85 to 7.45. The highest value was observed in the untreated banana sample (control) while the lowest value was observed in banana treated with hot water.

Table 4: Sensory Evaluation of Ripened Banana Samples

Parameter	Ca carbide	Potash	Hot water	Polythene	Control
Taste	$4.80^{d}\pm0.95$	$5.85^{c}\pm0.81$	$6.90^{b}\pm0.78$	$2.95^{e}\pm1.19$	$8.00^{a}\pm0.45$
Firmness	$6.45^{b}\pm1.05$	$5.35^{c}\pm0.93$	$6.65^{b}\pm0.74$	$5.75^{c}\pm0.78$	$7.95^{a}\pm0.60$
Appearance	$6.15^{c}\pm0.87$	$6.40^{b,c}\pm0.99$	$6.95^{b}\pm1.05$	$5.45^{d}\pm1.14$	$7.95^{a}\pm0.64$

Aroma	5.95^{c}±0.94	6.00^{c}±0.99	6.80^{b}±0.89	2.85^{d}±0.87	7.85^{a}±0.58
Mouthfeel	5.60^{c}±0.94	6.10^{c}±0.71	6.80^{b}±0.69	3.00^{d}±1.41	7.90^{a}±0.71
Acceptability	6.20^{b}±0.89	6.30^{b}±0.86	6.85^{a},b±0.67	3.85^{c}±1.56	7.45^{a}±0.75

Values are represented as means ± standard deviation of 20 panelist determination. Data in the same row bearing different superscript differed significantly ($p<0.05$).

DISCUSSION

Ripening Duration of Ripened Banana Samples

The ripening days was shortest in the calcium carbide treated samples and longest in the untreated samples. This result agrees with most research work in literature that ripening agents do increase ripening faster than when done naturally (Kesse, 2019). The use of artificial ripening agents helps farmers to reduce losses during fruit handling, predicts ripening time as well to timely release the product at desired ripening stage. Bananas can be artificially ripened using different ripening agents as indicated in the result obtained in this study. The effectiveness of calcium carbide when compared to other ripening agent in this study have been seen from the results obtained in this study. Ca Carbide reacts with water to produce acetylene, which acts as an artificial ripening agent. It can induce ripening of bananas by increasing the rate of respiration and increased level of endogenous ethylene. Studies have reported that low ethylene concentration as low as 0.1ppm is effective in accelerating the ripening of bananas (Maduwanthi and Marapana, 2019).

Physicochemical properties of ripened banana sample

The result of the physicochemical properties of ripened banana indicated that values for total soluble solid showed variability in banana samples treated with different ripening agents. Higher TSS value for calcium carbide ripened banana which was reported in this study while values reported by several authors as well as well as values reported for hot water induced ripening of banana were similar to the one obtained in this study (Maduwanthi and Marapana, 2019). Higher Total Soluble Sugar of the natural ripened fruits is could be associated with the breakdown of pectin and conversion of carbohydrate into simple sugars during storage and ripening caused by metabolic activities in the tissues. The results for the untreated banana sample ripened banana was comparatively similar to values reported in the literature (Kulkarini *et al*., 2004). The pH of the treated banana samples was significantly different for each treatment. Calcium carbide treated banana sample had the lowest pH value when compared to other samples. Similarly values reported for pH for hot water ripened banana and that reported was similar to value obtained for calcium carbide ripened plantain samples (Kesse, 2019; Maduwanthi and Marapana, 2019). Other authors also reported higher value of pH for calcium carbide ripened banana sample (Nura *et al*., 2018). Weight loss in the treated samples were higher for samples treated with hot water ripened banana sample. Similar studies on weight loss for banana fruit has been reported (Maduwanthi and Marapana, 2019). Higher weight loss in treated fruits may be attributed to the upsurge in the respiration rates by fruits during storage, accelerated evaporation rate from surface of fruits and burning of tissues of fruit surfaces

(Mahajan *et al*., 2008). The total titratable acidity of the artificial ripening was significantly different. Calcium carbide treated sample recorded the highest TTA value compared to other samples. Titratable acidity in this study was similar to those reported by other authors (Kaka *et al*., 2018). and higher than those reported for calcium carbide ripened banana samples (Nura *et al*., 2018). . High titratable acidity observed in the treated banana samples as compared to the untreated sample could be due, to faster ripening leading to incomplete hydrolysis of starch during the ripening process. The ripening process increases gluconeogenesis which is a metabolic pathway that generates glucose, hydrolyzes polysaccharides, decreases acidity and accumulates sugars and organic acids which may cause lower TTA and higher sugar content in ripened banana samples[11]. Furthermore, researchers have reported that high TTA might cause dental erosion, especially among children. Hence, regular consumption of artificially ripened banana could be harmful to dental health (Enam *et al*., 2016).

Proximate composition of ripened banana sample.

The proximate composition of the banana sample revealed that moisture content in artificial ripening was significantly higher than naturally ripened banana. Moisture content values of 73.8% in ripe bananas have been reported (Hakim *et al*., 2012). Other authors also reported similar moisture content values for calcium treated banana samples (Maduwanthi and Marapana, 2019). Moisture content in banana pulp is observed to increase because of respiratory breakdown of starch to sugar, migration of water from peel to pulp and excess moisture formation. Increase moisture content in artificial ripened banana samples is an indication that this artificial ripening weakens the fibre of the peel so that moisture is easily absorbed (Nura *et al*., 2018). The high moisture content of ripe banana contributes to its short storage life and high post-harvest loss. The result of the ash content in this study for calcium carbide ripened banana sample was higher than values reported by Enam *et al*., (2016) and at the same time lower than those reported for potash ripened banana sample (Sogo-Temi *et al*., 2014). Ash content relates to the inorganic mineral content of the sample, as this depicts that the concentration of mineral on the peel are absorbed by the edible portion of the fruit. The protein content of artificial ripened banana was significantly different among samples. Untreated banana sample recorded higher protein content 3.56% when compared to other samples. Researchers have reported similar protein values for calcium carbide and potash ripened banana samples (Sogo-Temi *et al*., 2014). This is also in agreement with study where it was observed a reduction in the protein content during ripening which may be due to reduction of nitrogen during ripening Enam *et al*., 2016). The carbohydrate content ranged between 21.75 to 27.60%. Banana samples treated with potash recorded higher carbohydrate content which is similar to that reported by other researcher (Sogo-Temi *et al*., 2014) while hot water treated samples recorded lower carbohydrate values. One of the biochemical changes occurring during ripening is a decrease in CHO in carbohydrates content. The starch is degraded by starch degrading α and β amylases which convert starch to simple sugars (Enam *et al*., 2016). The energy content was significantly different with the lowest value observed in hot water treated samples.

Mineral Composition of ripened banana samples

The mineral content of banana samples as influenced by traditional ripening methods indicated an increase in calcium content of samples treated with calcium carbide. Similar results have been reported by researchers on different banana and plantain cultivars ripened through the use of calcium carbide (Sogo-Temi *et al*., 2014; Adeyemi and Oladiji *et al*., 2009) This increase in calcium content may be attributed to diffusion of calcium ions from the calcium carbide into the banana fruit during the ripening process. Calcium is an essential macronutrient that is highly needed by the body for healthy bones and teeth among other body functions (Ukwo *et al.*, 2019). Its deficiency is more prevalent and damaging to human body than any other mineral (Oguntade and Fatumbi 2019). Similarly, excessive calcium in human body can cause constipation and also impede the body's ability to absorb other minerals like iron and zinc (Sogo-Temi *et al.*, 2014). Calcium carbide ripened banana samples gave the highest phosphorus content. The result obtained in this study have also been confirmed by some authors (Oguntade and Fatumbi, 2019). This increased in phosphorus have been attributed residual phosphorus that is sometimes present as impurities in calcium carbide used as ripening agent. Commercial grade calcium carbide is not usually in an a pure form, it contains impurities such as arsenic and phosphorus in the form of carbide arsenide (Ca_3As_2) and calcium phosphide (Ca_3P_2) (Igbinaduwa *et al.*, 2018). Banana samples ripened through the use of this traditional methods did not show variations in the values obtained for magnesium. Magnesium is an important components plant pigment chlorophyll which is usually converted to carotenoids during the ripening process in fruit. There is a usual reduction in the magnesium content of fruit during ripening (Sogo-Temi *et al.*, 2014). Values as obtained in this study did not indicate any significant effects of those ripening methods on the magnesium content of ripened banana samples. Phosphorus and magnesium are among the macronutrient that are highly needed for enzymatic and metabolic functions in human body.

Vitamin C content of ripened banana sample

The result of the Vitamin C content shows that Vitamin C decreases with application of ripening agents. The untreated banana recorded higher vitamin C content while the samples treated with potash recorded the lowest value. Studies have reported decrease in the Vitamin C content of artificially ripened cultivars while others have reported similar trend in Vitamin C. As per ripening chemistry, ascorbic acid decreases with increase in temperature (Njoke *et al.*, 2011). Banana sample treated with hot water and calcium carbide recorded the lowest Vitamin C content which could be due to the effect of increase in temperature and storage condition (Pokhrel 2014) .

Sensory evaluation.

The sensory evaluation in this study revealed that natural ripening of banana samples has excellent sensory quality with taste, firmness, appearance, aroma, mouth feel, and overall acceptability while artificial ripening agent like potash, calcium carbide, hot water and polythene bag do not. This agrees with those revealed in literature that natural ripening is best compared to artificial ripening and contribute to highest sensory acceptability[25,28]. The increase in taste and aroma of the untreated banana sample might be due to the formation of organic acids, alcohols, soluble sugars and other volatile compounds.

CONCLUSION

In recent days, artificial ripening agents are used worldwide due to economic reasons. Therefore, it is necessary to carry out the scientific research for the fundamental analysis of the ripening of fruits and fruits products, and point out the changes occurring in the artificially ripened fruits and its health effects. The analysis of artificially ripened fruits, physicochemical properties and health effects of the adulterated food is an energetic process. In the present study, the physicochemical properties of the artificially and naturally ripened fruit (banana) with no ripening agents were assessed and compared. Titrable acidity and total soluble solids showed significant changes in artificially and naturally ripened banana samples with no ripening agents. The titrable acidity of chemically ripened banana was higher than the naturally ripened banana. Naturally ripened banana gained higher acceptability compared to artificial ripened samples. However, ripening occurred faster in samples treated artificially than natural, used as control. Thus, with artificial ripening agents, fast ripening is achievable for economic purposes.

SIGNIFICANCE STATEMENT

Banana is a climactic fruit that is usually induced to ripe essentially in commercial scale to assure availability, reduction in postharvest losses as well as enhancing good flavour, and uniform peel colour. However, artificially ripening of banana is considered as a matter of concern due to some perceive health-related issues. This study addresses the changes in some nutritional composition associated with artificial ripening of banana fruit. The findings of this study will be very significant for the consumers, researchers, legal authorities and other stakeholders involve on food safety, food processing and preservation.

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