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Assessment of Quality Characteristics of Organic and Conventional Sugarloaf Pineapples (*Ananas comosus*, *ananas*) Under Cold Storage

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Abstract
Fresh pineapple is an excellent source of vitamin C and there is a big demand for organically produced sugar-loaf pineapples in Europe. However, due to its high moisture content and high perishability, transportation over long distances is difficult and require cold storage conditions. The main objective of this research was to assess the quality properties of organic and conventional sugar loaf pineapples under cold storage conditions over a 21 – day period. Conventional pineapples were harvested from Albe Farms in the Eastern region and organic pineapples from Ali farms in the Central regions of Ghana. The fruits were allowed to cool to room temperature before storing at 1°C. Physical and chemical properties of the fruits were determined at days 0, 7, 14 and 21, using standard methods. Conventional sugar-loaf pineapples were larger, but had lower dry matter, soluble solids and vitamin C, than organic pineapples. The weight, translucency and pH of the two categories of pineapples were similar. No significant loss in weight, lengths and crown characteristics were observed after the storage period. Translucency increased from <25% to a range of 50 – 75% by the end of the storage period in both organic and conventional fruits. While no clear trend was observed in the soluble solids content and pH during storage of both organic and conventional sugarloaf pineapple, total titratable acidity increased marginally and vitamin C levels dipped over the 21-day storage period. The trends in acidity, vitamin C and translucency suggest that it is possible to store both conventional and organic sugarloaf pineapple for 21-day storage period at 1 °C. This implies the possibility of shipping both organic and conventional sugarloaf pineapples to destinations requiring sea freighting.

Keywords: Conventional sugarloaf, Organic sugarloaf, Pineapple, Sea-freighting, Shelf-life

Évaluation des caractéristiques de qualité des ananas sugarloaf *(Ananas comosus, ananas*) biologiques et conventionnels en stockage à froid

Résumé
L'ananas frais est une excellente source de vitamine C et il existe une forte demande d'ananas en pain de sucre de production biologique en Europe. Cependant, en raison de sa forte teneur en humidité et de sa grande périssabilité, son transport sur de longues distances est difficile et nécessite des conditions de stockage à froid. L'objectif principal de cette recherche était d'évaluer les propriétés de qualité des ananas en pain de sucre biologiques et conventionnels dans des

conditions d'entreposage à froid sur une période de 21 jours. Les ananas conventionnels ont été récoltés dans les fermes d'Albe dans la région de l'Est et les ananas biologiques dans les fermes d'Ali dans les régions centrales du Ghana. On a laissé les fruits refroidir à température ambiante avant de les stocker à 1°C. Les propriétés physiques et chimiques des fruits ont été déterminées aux jours 0, 7, 14 et 21, selon des méthodes standard. Les ananas conventionnels en pain de sucre étaient plus gros, mais avaient moins de matière sèche, de solides solubles et de vitamine C que les ananas biologiques. Le poids, la translucidité et le pH des deux catégories d'ananas étaient similaires. Aucune perte significative du poids, des longueurs et des caractéristiques de la couronne n'a été observée après la période d'entreposage. La translucidité est passée de <25 % à une fourchette de 50 à 75 % à la fin de la période d'entreposage, tant pour les fruits biologiques que conventionnels. Bien qu'aucune tendance claire n'ait été observée en ce qui concerne la teneur en solides solubles et le pH pendant l'entreposage des ananas en pain de sucre biologiques et conventionnels, l'acidité totale titrable a augmenté de façon marginale et les niveaux de vitamine C ont chuté au cours de la période d'entreposage de 21 jours. Les tendances de l'acidité, de la vitamine C et de la translucidité suggèrent qu'il est possible de conserver les ananas en pain de sucre conventionnels et biologiques à 1 °C pendant 21 jours. Cela implique la possibilité d'expédier des ananas en pain de sucre biologiques et conventionnels vers des destinations nécessitant un transport maritime.

Mots clés: Pain de sucre conventionnel, Pain de sucre biologique, Ananas, Transport maritime, Durée de conservation

Introduction

Pineapple (*Ananas comosus* L.) is the third most important tropical fruit globally, after banana and citrus. It is cultivated in all tropical and subtropical countries. The global pineapple production in 2020 amounted to approximately 27.82 million metric tonnes (FAOSTAT, 2022). Ghana's pineapple industry has grown significantly over the past two decades, with a significant percentage of the produce exported. In 2008 for instance, 35,601MT out of the 70,000 MT produced was exported, making up 4% of world exports to the European Union (FAO, 2014), where France is the largest destination. Key varieties for commercial export include MD2, Smooth cayenne, and Sugarloaf.

Pineapple is popular because of its unique flavor and refreshing sugar-acid balance. It is available fresh and in many other processed forms such as canned chunks, juice, among others. In general, 100g pineapple contains 47-52 calories, 85.3-87.0g water, 0.4-0.7g protein, 0.2-0.3g fat, 11.6-13.7g total carbohydrate, 0.4-0.5g fibre, 0.3-0.4g ash, 17-18mg calcium, 8-12mg phosphorus, 0.5mg iron, 1-2mg sodium and 125-146mg potassium. Pineapple is extremely rich in vitamin C, which protects the body from free radicals that cause atherosclerosis, bronchitis and heart disease. It has a beneficial effect on the proper functioning of the immune system (Coveca, 2002).

While MD2, followed by smooth cayenne, is the dominant export variety of interest, a small but significant market also prefers sugarloaf, especially for juice processing. The sugarloaf cultivar has a conical shape, pale flesh colour and tastes sweet with little acidity. Fruit size may range from 0.5-1.5 kg. The sugarloaf pineapple is smaller in size and stays green even when ripe and features a brighter pearl white fruit, with a soft edible core. The brix of ripe sugarloaf may range from 14.7 to 17.1°Bx (Owureku-Asare *et al*., 2015). Even though Morton (1987) considered this cultivar too tender for sea freighting, a recent study by Owureku- Asare *et al,* (2015) suggests that the sugarloaf is strong and could therefore be suitable for shipment by sea.

As consumer demand for organic food grows, organic certification is encouraged in many developing countries. Studies have recently found that certified organic agriculture is more profitable than conven-tional agriculture in developing countries, due to the higher price farmers receive for their products (Bolwig *et al*., 2009; Maertens and Swinnen., 2009). Rieple and Singh (2010) have shown that organic production adds value throughout the production and processing of commodities such as cotton. Other studies have explained the size of the premium and the willingness to pay a premium for organic products (Teisl *et al*., 2002; Nimon and Beghin, 1999; Bjorner *et al*., 2004). Like other organic products, organic pineapple earns a premium price. Hence, the shift from conventional to organic production might be an opportunity for small-scale farmers to reap higher returns from their investment.

Quality criteria set forth by the Codex Alimentarius (2005) include degree of acceptability, fruit weight, fruit height, crown to fruit ratio, total soluble solids and percentage damage. Further, Steir (1994), indicates that pineapples of good market quality must have a good appearance, clean and free from foreign matter, insect or mechanical damage, and be fully ripe. In particular, the soluble solids content must be 12 – 14°Bx or higher, with an acid content of 12 – 18% meq, sugar to acid ratio of 1, translucency between 30-40%. These specifications can be maintained when the fruits are kept under strict temperature regimes. Abdullah *et al* (1994) reported that some varieties of pineapples may have a shelf life of 3-4 weeks when kept at temperatures between 8 and 10°C.

Currently, pineapples are exported from Ghana to Europe by air. However, the potential for a cheaper alternative such as sea-freighting, exists. The only drawback to this approach is the relatively longer transport durations of more than two weeks (Behnke, 1994), given the delicate and perishable nature of pineapples. That notwithstanding, with the right storage conditions, it is possible to extend the shelf life of the fruits for a few days longer to make transportation by sea successful. The objective of this study was, therefore, to compare physical and chemical quality of organic and conventional sugarloaf pineapple and to determine their stability under simulated sea-freight conditions.

Materials and Methods

Conventional pineapples were harvested from Albe Farms in the Eastern region and organic pineapples from Ali farms in the Central regions of Ghana, which is a hub for sugarloaf pineapple production. Convent-ional and organic grown sugar loaf pineapples of 150 days and 135 days respectively, were studied. The samples were harvested and transported to the laboratory immediately after harvest and left to cool to room temperature overnight, before storage experiments. Three independent batches of the fruits were used in the entire experiment.

Storage Experiments

Pineapple samples were stored in a climatic chamber at simulated sea-freight conditions for horticultural crops (1° C and 80% RH) for 21 days (Goedhals-Gerber *et al*., 2017). On a weekly basis, fruits were sampled for physical and chemical analyses.

Physical measurements

Fruit and crown weight

The fruits were weighed separately (after detaching the crown from the fruit) using an electronic balance (Kern 510, Kern & Sohn GMbH, Germany). Crown to fruit ratio was calculated from these measurements.

Length of crown and core diameter

Crown length was measured with a measuring tape as the tip of the crown to the point at which the crown touches the fruit. Random samples of fruit were sliced horizontally at the point of the largest diameter and the diameter of the core measure with a digital caliper (Mitutoyo, Japan).

Translucency

Fruit translucency was determined using a pineapple colour chart (Haff *et al*., 2006). Translucency was reported as "<25%", "25-50%" and "50-75%" after cutting the pineapple fruit cylindrically.

Chemical analysis

Chemical analyses were carried out on fresh juice extracted from the pineapple fruits.

pH and Brix

The pH of the juice was determined with a calibrated pH meter (Jenway Research pH meter 3330, UK) using standard methods of the AOAC International (AACC 2000). Brix was determined using an Abbe Refractometer (Bellingham Stanley Limited, Kent Limited, UK)

Total Titratable Acidity (as % citric acid) and sugar-acid ratio

Total Titratable Acidity (TTA) was determined using titrimetry (AOAC 2000). Ten milliliters of juice extracted from the sugarloaf pineapples was titrated against NaOH solution (0.1 N) using phenolphthalein as indicator. TTA, expressed as percent citric acid, was calculated using the formula:

$$\text{TTA (\%)} \quad \frac{\text{Titre value x Normality of NaOH x M.eq.wt of acid x 100}}{\text{Volume of sample}}$$

Where *M.eq.wt* of acid is 0.06404

Sugar-acid ratio

The sugar-acid ratio was calculated as the ratio of soluble solids (°Bx) to TTA.

Vitamin C

Vitamin C was determined by the Di-chloroindophenol method as outlined in 967.21 of the Association of Official Analytical Chemists (AOAC, 1990).

Statistical Analysis

Data obtained for the study were analyzed using Repeated Measures ANOVA in which the dependent variables were use as response, and storage time and pineapple cultivar were used as condition and subject respectively (Statgraphics Centurion 19, Statgraphics Inc., USA). Statistical analyses were conducted at a 95% confidence interval, and means separated by Duncan's Multiple Range Test ($p=0.05$).

Results and discussion

The weight of organic and conventional pineapples ranged from 0.90 to 1.10kg and 1.13 to 1.63kg, respectively (Table 1). The length of organic and conventional fruits respectively ranged from 21.7 to 22.7cm and 22.1 to 26.6cm. Also, the length of organic crown ranged from 15.5 to 22.9cm whereas conventional fruits ranged from 19.1 to 26.3cm. Crown weight, crown to fruit ratio and core diameter for both types of pineapple were similar ($F=4.21$, $p=0.120$). The results showed that conventional fruits were significantly longer ($F=6.34$, $p=0.014$) and heavier ($F=13.10$, $p=0.001$) than organic fruits (Table 2). Whereas translucency from the 0 - day of storage ranged from 25-50 in organic sugar loaf, the conventional sugar loaf pineapples showed a translucency of <25-50.

During the 21-day storage period, there were no significant changes in physical properties of the fruits, except for translucency, which increased to between 50 – 75%. Even though an understanding of the causes of pineapple translucency remains a matter of conjecture, Paull and Chen (2015) suggest that accumulation of sugars and fruit calcium levels are among the factors that promote fruit translucency. Chilling injury inflicted by the low storage temperature of 1 °C, may have also induced translucency. Translucency is an important attribute that affects the eating quality of pineapples. Highly translucent fruits are considered overripe, whereas low translucency is characteristic of unripe or semi-ripe (Bartels, 1997). Overripe fruits may not have a pleasant eating quality but may be suitable for pineapple juice production. Nevertheless, highly translucent fruits are prone to mechanical damage and microbial attack (Paull and Chen, 2015) leading to spoilage and reduction in market value of fruits. The storage conditions prevented excessive changes in fruit weight. At such low temperatures, metabolic activities such as respiration are reduced. For instance, a rate of respiration of 2 mg CO_2 $kg^{-1}h^{-1}$ occurs at 5 °C,

Table 1: Physical characteristics of organic and conventional Sugarloaf pineapple

Day of storage	Type of pineapple	Weight of fruits (kg)	Weight of Crown (kg)	Crown-to-fruit-ratio	Length of fruit (cm)	Length of crown (cm)	Core diameter (cm)	Translucency (%)
0	Organic	1.07±0.13	0.16±0.04	0.16±0.04	22.6±2.2	22.7±4.9	2.0±0.2	25-50
	Conventional	1.22±0.10	0.16±0.02	0.16±0.18	25.4±1.2	23.1±1.7	2.0±0.2	<25-50
7	Organic	1.10±0.07	0.18±0.04	0.16±0.04	22.7±2.1	15.5±1.9	2.3±0.1	50-75
	Conventional	1.28±0.04	0.18±0.04	0.14±0.02	26.6±0.7	19.1±4.0	2.1±0.2	50-75
14	Organic	1.03±0.14	0.15±0.03	0.14±0.03	22.4±4.2	22.9±1.2	2.1±0.3	25-50
	Conventional	1.13±0.12	0.14±0.03	0.09±0.01	22.1±2.1	24.7±1.4	2.1±0.2	25-50
21	Organic	0.90±0.13	0.13±0.03	0.15±0.03	21.7±1.8	20.5±3.5	2.1±0.2	50-75
	Conventional	1.63±0.16	0.14±0.03	0.09±0.01	23.7±0.8	26.3±0.8	2.2±0.1	50-75

Table 2: Treatment effect on the physical properties of organic and conventional sugarloaf pineapples

Source of variation	F-ratio/p-value					
	Weight of fruits (kg)	Weight of Crown (kg)	Crown-to-fruit-ratio	Length of fruit (cm)	Length of crown (cm)	Core diameter (cm)
Storage period	1.49/0.121	2.11/0.104	1.89/0.411	5.49/0.073	2.33/0.173	2.29/0.082
Variety	13.10/0.001	0.01/0.933	1.02/0.613	6.34/0.014	4.05/0.060	0.56/0.454
Storage period*variety	0.26/0.852	0.09/0.965	0.95/0.412	5.36/0.400	1.86/0.141	2.22/0.090

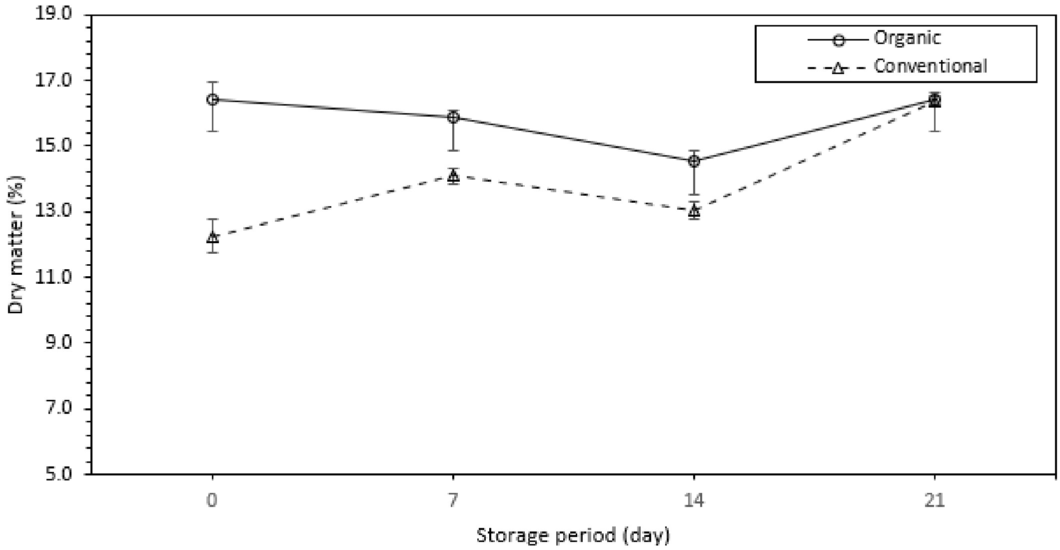

Figure 1: Dry matter content of sugar loaf pineapples during storage

compared to 10 – 16 mg CO_2 $kg^{-1}h^{-1}$, at 15 °C (Paull and Chen, 2011). Reduction in these biochemical activities at low temperatures reduces extreme moisture loss and wilting. Visually, the crown did not appear shriveled or wilted after the 21-day storage period. This agrees with the results of Abdullah *et al*., (1996) who found no deterioration in crown quality after four weeks of storage, albeit at a higher temperature of 10 °C

The organic pineapples had a higher dry matter (Figure 1), and by extension would ordinarily have less juice compared to conventional sugar loaf which was the heavier of the two. This index may prove useful in juice processing, where lower dry matter is preferred. A slight fluctuation was recorded in fruit dry matter over the storage period. Organic fruits had a decreased dry matter in the first two weeks but the dry matter increased slightly by day 21 of storage. Conventional fruits, on the other hand, showed a slight increase throughout the storage period. The dry matter of Organic fruits decreased by 1.89% by 14 day. Conventional fruits, on the other hand showed a slight increase of 0.3%. Although the reason for this trend remains unknown, it is believed that some biochemical processes may be responsible for this observation. Proper storage conditions such as temperature and humidity are needed to lengthen storage life and maintain the quality of harvested fruits. Fresh fruits need low temperature and high relative humidity to reduce respiration and slow down metabolic activities.

Figure 2 shows total soluble solids content of organic and conventional sugar loaf pineapple during 21 days of storage under refrigeration at 1°C. As indicated by Masniza *et al* (2008), pineapple contains 12-15 % sugars of which two-thirds are in the form of sucrose and the rest are glucose and fructose. In this study, the initial total soluble solids (TSS) of organic and conventional were 13.51 °Bx and 11.96 °Bx, respectively. These values are lower than

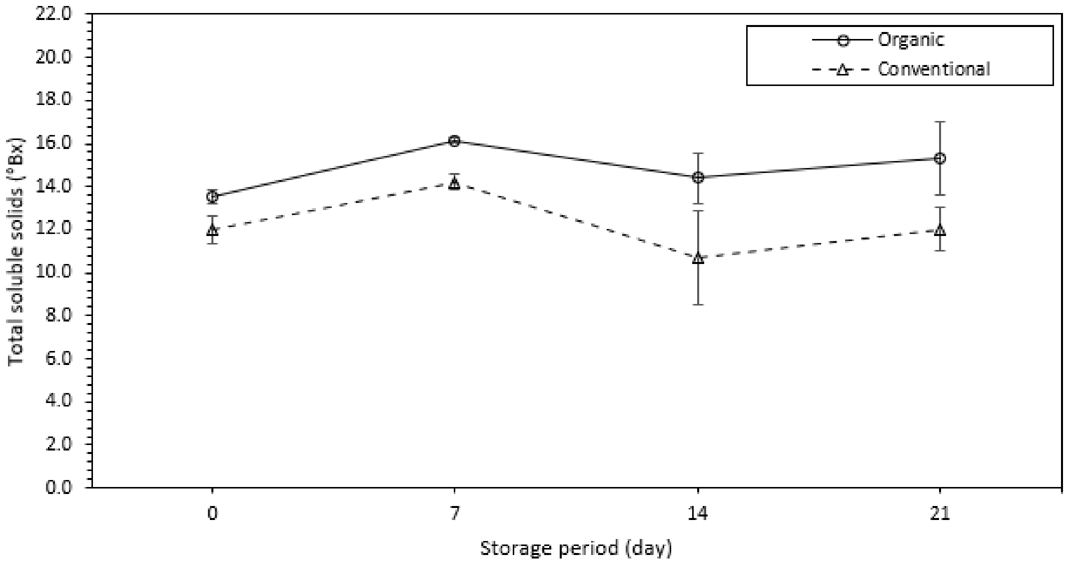

Figure 2: Brix levels of organic and conventional sugar loaf pineapples during storage

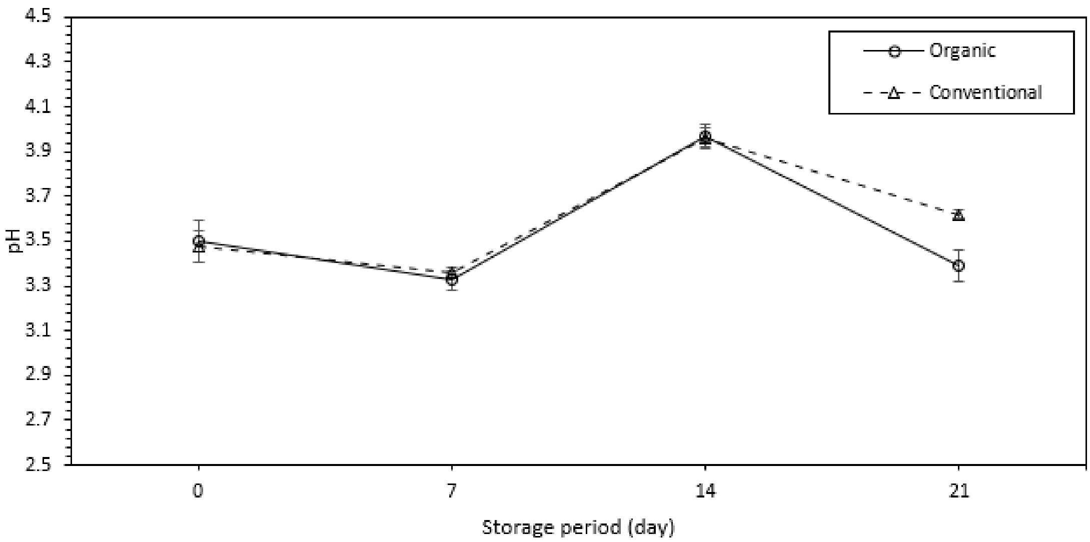

Figure 3: pH of organic and conventional sugar loaf pineapples during storage

values of (15 – 16.2 °Bx) and (16.75 °Bx) reported in previous studies for conventional sugar loaf pineapple by Owureku-Asare *et al*., (2015) and Wardy *et al.,* (2009) respectively.

Even though no clear trend was observed during the storage, a marginally higher TSS was recorded after the 21-day storage period in both organic and conventional pineapples. Sugar content of pineapple may increase after harvest. However, the fruits were kept under cold storage, and under these conditions, enzyme activities which are responsible for structural carbohydrate hydrolysis into simple sugars are minimized. Earlier studies by Abdullah and Rohaya (1996) and Mohammed and Wickham (1995) also found no significant changes in the sugar level of pineapple under low temperature storage.

The mean pH of the sugarloaf pineapples was 3.49, and comparable to the range of 3.5 – 4.5 reported by Kongsuwan *et al*., (2009) for pineapples, 3.42 – 4.22 for sugarloaf pineapples (Owureku Asare *et al*., 2015) but lower than 4.96 recorded by Wardy *et al* (2009) for sugarloaf pineapples (Figure 3). Repeated measures ANOVA revealed significant increase ($F=20.80$, $p=0.0164$) in the pH of the pineapples by the end of the study period of 21 days. This increase was not expected, and may be due to natural variations in pineapples which is known to be highly heterogeneous in quality at harvest (Hotegni *et al*., 2014). Sugar loaf (organic and conventional) showed lower pH values during storage period except for 14 weeks of storage which showed a slight increase in pH from 3.33 to 3.98 (organic) and 3.36 to 3.96 (conventional fruits).

Total titratable acidity (TTA) measures the total acids in the pineapple fruits. Ripening is known to reduce acid levels in fruits (Lacey *et al*., 2009). During ripening the acids are involved in protein synthesis resulting in a decrease in TTA. Organic fruits had higher TTA values (0.95 %) than conventional fruits (0.86 %) (Figure 4). These levels are higher than 0.49 – 0.66% reported for conventional sugarloaf pineapple by Owureku-Asare *et al* (2015) but comparable to 1.1% reported by Wardy *et al*., (2009) for sugarloaf pineapple and 0.5 - 1.6 % by Paull and Chen (2014) for pineapples in general. Acidity levels among the two pineapple categories increased over the storage period. At the end of 21 days of storage, an acidity of 1.05% and 1.02% were respectively recorded for organic and conventional sugarloaf pineapple. Increase in acidity of the pineapples may be desirable since it enhances the storage life and astringency index (Wardy *et al*., 2009). This may be very useful for juice processors as longer shelf life allows sufficient time for handling, processing and selling. Dharamadhikari (2007) established that higher acidity of fruit juices is often associated with lower pH values, as observed in this study.

Figure 5 shows sugar to acid ratio of organic and conventional sugar loaf pineapple during 21 days of storage under refrigeration temperature of 1°C. The sugar to acid ratio was greater than 1, an indication that the level of sugar in both sugarloaf types was higher than the acids, and therefore the fruits will taste sweet and not sour. Organic fruits had high values for sugar to acid ratio compared to the conventional sugarloaf, during 21 days of storage. This is possible since research has shown an association between soil amendment and acidity and brix of fruits (Souza *et al*., 1991; Py *et al*., 1987). For instance, Owureku-Asare *et al*., (2015) found a reduction in the brix of sugarloaf pineapple when the amount of nitrogen fertilizer was increased. Repeated measures ANOVA showed a significant change ($F=13.6$, $p=0.0298$) in sugar-acid ratio over the storage period. The sugar-acid ratio is a prominent

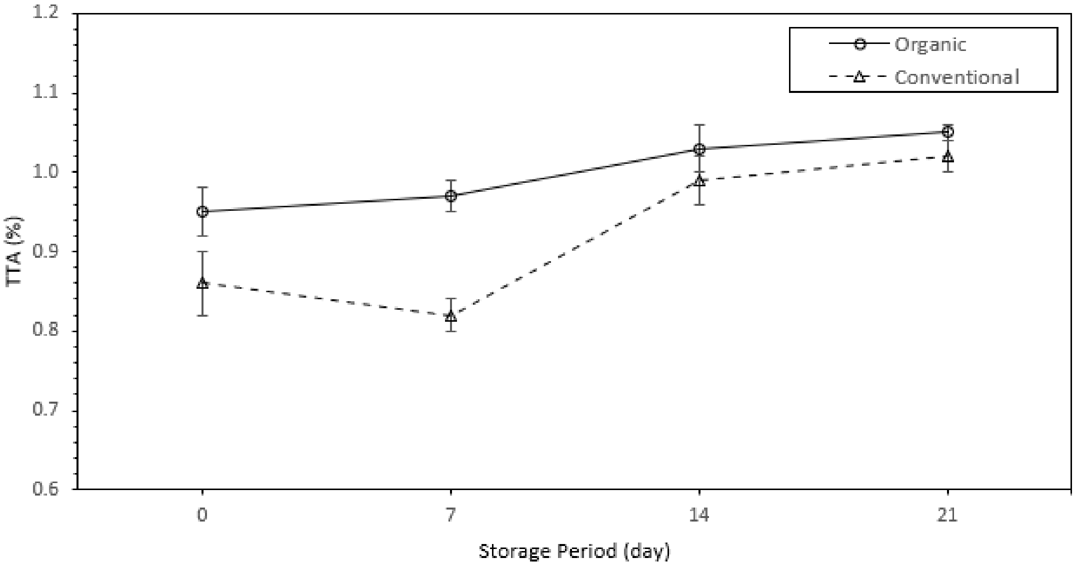

Figure 4: Titratable acidity (TTA) of organic and conventional sugar loaf pineapples during storage

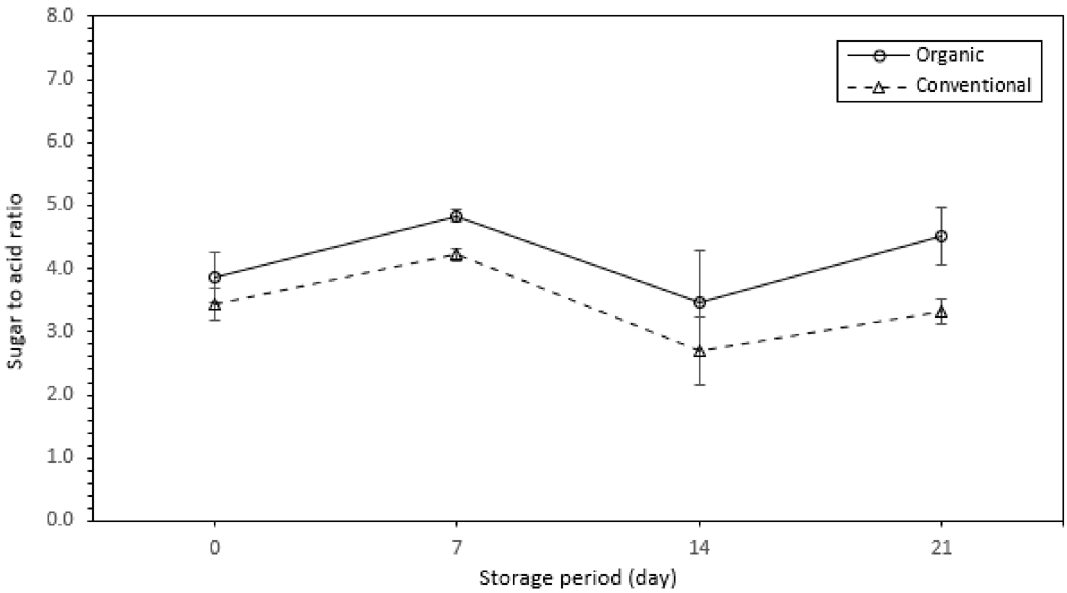

Figure 5: Sugar to acid ratio of organic and conventional sugar loaf pineapples during storage

factor for consumer acceptance because it directly influences the taste of fruits. The increased value of sugar to acid ratio during 7th and 21st day of storage could be due to higher total soluble solids value and lower acidity values. According to Jintana *et al*., (2009), sugar acid ratio affects the taste of the pineapple juice, and therefore, its acceptability.

Vitamin C is an important nutrient with an efficient antioxidant functionality, which prevents scurvy and contributes to reducing artherogenesis (Lee and Kader, 2000; Sanchez-Moreno *et al*., 2003). In this study, the organic sugarloaf pineapple had a higher concentration of vitamin C than the conventional pineapple at harvest. The initial concentration of vitamin C in organic and conventional sugar loaf pineapples were 33.02 and 23.66 mg/100g, respectively (Figure 6), which were lower than values reported for sugarloaf pineapple (38.9 – 52.0 mg/100 g and 42.1 mg/100 g) by Owureku-Asare *et al*., (2015) and Wardy *et al* (2009). Values obtained in the present study were within the range of 18 to 56.4 mg/100 g as reported by the USDA (2009) for pineapples. Generally, vitamin C levels in pineapple range from 20 to 65 mg/100g of its fresh weight, depending on the cultivar and stage of maturity (Infoagro, 2002). Smith (2003) however suggests a lower range of 10-25 mg/100g. Over the 21-day storage period, changes in vitamin C content for both fruits followed the same trend. At the end of the storage period, whereas a significant decrease in vitamin C was recorded in the organic sugarloaf, a negligible increase occurred in the conventional sugarloaf. Generally, the vitamin C content of fruits gradually reduced in storage. It is possible that chilling injuries occurring during the storage of the pineapples, may have contributed to vitamin C loss (Lee and Kader, 2000). Results of the present study show a similar trend to work

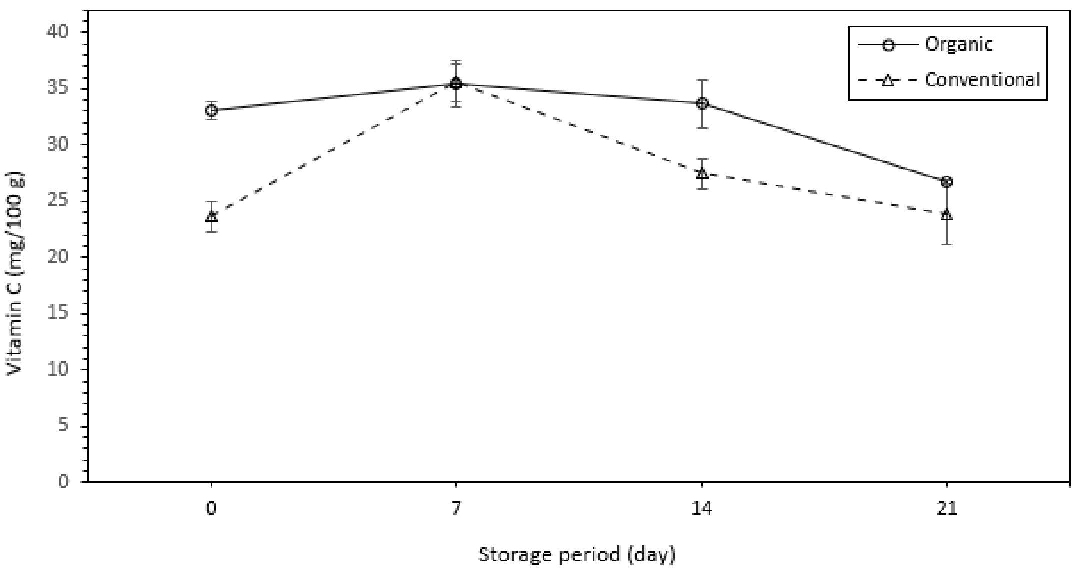

Figure 6: Vitamin C of organic and conventional sugar loaf pineapples during storage

done by Hu *et al*., (2011) where pineapples had its vitamin C content decreasing at the end of 21-day storage period at 7°C.

Conclusions

From the present study, conventional sugar-loaf pineapples were notably larger compared to organic sugarloaf pineapples. There were no excessive changes in the physical properties, such as weight, length, crown and core dimensions, of both organic and conventional fruits during storage at 1°C and 80% RH. However, higher translucency of 50 – 75%, was recorded in both organic and conventional fruits at the end of the storage period of 21 days. Also, there were slight alterations in some chemical indices. Total titratable acidity increased in both organic and conventional pineapples. The pH, brix and vitamin C levels recorded over the storage period in organic and conventional pineapples were acceptable and did not indicate spoilage or adverse chemical loss. The storage conditions used in this study did not adversely affect the quality characteristics of organic and conventional sugarloaf pineapple.

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