Possibility of sea-freighting bio-sugarloaf pineapples (Reference number MAT17GH01)S

Physicochemical, shelf-life and sensory characteristics of conventional and organic sugar-loaf pineapples stored at two temperatures.

By

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Table of Contents

Summary

The pineapple (*Ananas comosus*) is a tropical plant with edible fruit of the *Bromiliaceae* family, having several different cultivars or types. They are non-climacteric fruits, i.e. they must be harvested ripe because it will not continue to ripen once harvested. Fresh pineapple is an excellent

source of vitamin C. The sugar-loaf pineapple is smaller in size than other varieties, stay green even when ripe and feature a brighter pearl white fruit, with a soft edible core.

There is a big demand for organically produced sugar-loaf pineapples in Europe. At this stage, however, sugar-loaf can only be air-freighted. Studies have indicated that organically grown sugar-loaf is stronger and has a longer shelf life that could be suitable for export market. This makes exporting the sugar-loaf pineapple by sea seemingly possible under the right conditions of temperature and humidity. The main objective of this research was to assess the possibility of sea-freighting organic sugar-loaf pineapples by comparing the shelf-stability of conventional and organic pineapples.

Conventional and organic grown sugar loaf pineapples of 150 days (8 month age of forcing) and age 135 days (11months age of forcing) respectively were studied. Conventional pineapples were harvested from Albe Farms in the Eastern region and organic pineapples from Ali farms in the Central regions of Ghana. Three batches of the pineapples were supplied. Physical characteristics (fruit weight, fruit length, crown weight, crown length, crown to fruit ratio, core diameter and translucency) were determined. Chemical properties (pH, brix, titratable acidity and vitamin C) were also determined. These properties were assessed at a baseline (after harvest) and after storing for 14 days at 1 °C or 8 °C.

Generally, organic pineapples had large fruits compared to conventional pineapples. The conventional pineapples had a short shelf-stability than organic pineapples. The pH values for the organic pineapples was lower than the conventional pineapples while the acidity of the organic sugar-loaf pineapples was higher than the conventional. The vitamin c content for the baseline organic sugar-loaf pineapples varied from 25.22 to 33.02 mg/100 ml and that for conventional pineapples 19.69-23.66 mg/100 ml. Generally, conventional sugar-loaf stored at 8°C attained a higher translucency (50-75%). Although Vitamin C was generally lower after storage (compared to the baseline), organic sugar-loaf stored at 1°C and 8°C had higher Vitamin C compared to the conventional pineapples. Lower acidities were also observed in both types of sugar-loaf pineapples after storage.

Organic sugar-loaf pineapples stored at 1°C and 8°C largely had 25-50% translucency after storage. Only 16% and 8% of the organic fruits recorded 50-75% translucency for after storing at 1°C and 8°C correspondingly. Conversely, a majority (52.3%) of conventional sugar-loaf pineapples at 1°C recorded 50-75% translucency. These results suggest that the organic sugar-loaf pineapples will have a longer shelf-life under refrigerated conditions. Using proper handling and packaging methods and the right conditions (1°C and 8°C), it is may be possible to sea-freight organic pineapples to Europe because it can thrive at both temperatures without spoilage.

1.0 Introduction

Pineapple is the second harvest of importance after bananas, contributing to over 20 % of the world production of tropical fruits (Coveca, 2002). Nearly 70% of the pineapple is consumed as fresh fruit in producing countries. Pineapples come in a range of sizes and shapes, such as the following types: Round, Oval and Conical. Pineapples contain 81.2 to 86.2% moisture, and 13-19% total solids, of which sucrose, glucose and fructose are the main components. Carbohydrates represent up to 85% of total solids whereas fiber makes up for 2-3%. Of the organic acids, citric acid is the most abundant. The pulp has very low ash content, nitrogenous compounds and lipids (0.1%). From 25-30% of nitrogenous compounds are true protein. Fresh pineapple contains minerals as calcium, chlorine, potassium, phosphorus and sodium. The most important cultivars available on the EU markets are Smooth cayenne, MD2, Sugar loaf and Queen Victoria

Until the mid-1990s, Smooth Cayenne was the cultivar primarily used for the fresh pineapple trade, with the majority of fresh pineapple exports being produced in West and Central Africa. The fruit was renowned for its characteristic orange/yellow colour and peculiar taste. Ripe fruits had a mixed acid/sugar taste. Smooth Cayenne is exported to the EU by sea or air freight.

MD-2 or Extra Sweet is a hybrid introduced to the trade by the Del Monte Company. Although developed in Hawaii, MD-2 (Extra Sweet) was first grown commercially in Costa Rica before spreading to other Latin American countries (Ecuador, Panama and Honduras) but is now also grown in Africa (Ghana and Côte d'Ivoire). This cultivar is not as coloured as Smooth Cayenne, its flesh is more coloured than the colour of the Smooth Cayenne. More important, the fruit is very sweet without an acidic taste. The high sugar content producing very sweet tasting fruit has boosted pineapple consumption as well as fresh pineapple exports worldwide these past 20 years.

The Sugar-loaf cultivar are less well known, largely due to the fruit only being grown and exported from specific countries, mainly West Africa. The fruit is easily recognizable by its bottle shape. Sugar- loaf' pineapples are the sweetest in flavor among the cultivars produced in Ghana. However, the skin is very delicate and the fruit has a short shelf- life. The fruit is oblong in shape and averages about 2 kg in weight. Skin color is dark green when mature and changes to bright yellow as the fruit ripens. It is highly aromatic when fully ripe. Depending on the soils on which they are grown, fruits of this cultivar are either dark green (Ghana) or coloured (Benin) or somewhere in between (Togo). Sugar-loaf pineapples are only transported by air freight. Sugar-loaf pineapples are entirely edible up to their core, which is rather soft and a bit crunchy. The high sugar content lends well to caramelizing and browning.

The trade as well as specific fruit retailers consider Queen Victoria as "small exotics". Although most of the production available on the EU markets originates from the Indian Ocean (South Africa, Mauritius and Reunion), some occasionally come from Africa (Ghana). These fruits are only available through the air freight market (CBI Market Information).

Definition of produce

Smooth Cayenne

Queen Victoria

MD2

Sugar Loaf

The trade in sugar-loaf pineapples, at least on EU markets, is rather recent (past 5–6 years) in comparison to the trade of the other pineapple cultivars. Like all other pineapples, sugar-loaf is harvested ripe. Depending on the soil on which the fruit is grown the flesh of the fruit can vary between white and pale yellow. Brix percentages in ripe sugar-loaf generally range between 13.5 and 15%. The difference in sweetness between the base and the top is not pronounced.

Organic agriculture is defined as farming in an ecologically and socially responsible way providing an enduring supply of safe and healthy food and having the least possible nutrient and energy losses. It also focuses on having the least possible negative environmental impacts, respecting the integrity of plants, animals, and life sustaining soil being regulated by certification/third party agencies. Organic agriculture goes further than no usage of pesticides and chemical fertilisers. Organic farming presents a lot of benefits to farmers, which are: Less input – less capital needed, Premium prices which increases farmer's income, less health risks for farmers and consumers, less damage to environment, can build on traditional knowledge and access to new (organic) markets. For the local sugar loaf variety a field trial has shown that organic fertilizers such as cocoa husk or compost give better results in terms of ripeness after a certain number of months, levels of pH and acidity, crown size and fruit weight. This might not be true for other varieties, but shows that production is not necessarily faster and more efficient when chemical inputs are used.

Ghana is the second largest African pineapple exporter to Europe after Côte d'Ivoire and is expected to increase its market share (Pay, 2009). The market for organic pineapple is still a niche market. However, not only did the demand for pineapple in general increase over time, but organically grown pineapple have also become more popular among consumers. Like other organic products, organic pineapple earns a premium price on the market compared to conventional varieties. Hence, the shift from conventional to organic production might be an opportunity for small-scale farmers to reap higher returns from their investments. If viable, this would be highly interesting for development actors, as small-holders include the majority of the absolute poor in developing countries. Since the switch from conventional to organic production technologies requires costly adjustments of the land, for example, several aspects of the market need to be considered when trying to determine its profitability.

A few studies have recently found that certified organic agriculture is more profitable than conventional agriculture in developing countries, due to the higher price farmers receive for their product (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 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). Among small-holder farms, organic production is more advantageous than conventional production. This suggests that in percentage terms, organic price premiums are fully passed from retail level to Ghanaian farmers. Most organic pineapples for the EU market are produced in Ghana with an increasing amount coming from Costa Rica (CBI, 2008).

Organic production is often seen as a valuable alternative for developing countries with many small-holders. It is more profitable for smallholders than conventional production and farmers collect a fair share of the price premium on the retail level (Kleemann, 2011). Production of sugar loaf is concentrated in the Mfantseman District of the Central Region of Ghana. Most fruits are for the local market. This is because sugar loaf has a very high sugar content (approx. 24g/100) with 13.5-15% brix as compared to the Smooth Cayenne and MD2 (around 11g) with 12.8-14% brix (CBI Market Information Database • URL: www.cbi.eu) . This makes it not conducive for sea-freighting for weeks to Europe. Studies done by Owureku- Asare *et al,* (2015) has indicated that organically grown sugar loaf is stronger, would have longer shelf -life and could be suitable for export market. There is a big demand for organically produced sugar-loaf pineapples in Europe. Currently, these pineapples can only be air-freighted to Europe and is very expensive. A growing number of people are however convinced that export of organically produced sugar-loaf by sea is also possible under the right conditions.

The main objective of this research was to determine the effects of organic and conventional farming on physical and chemical quality of sugar loaf pineapple (*Ananas comosus L.*) cultivated in two different sites in Ghana. The effect of organic and conventional farming on the shelf-stability of sea-freighted sugar-loaf pineapples targeting the export market.

1.1 Objectives

1. To determine the physical properties of organic and conventional sugar loaf pineapples from two different locations.
2. To determine the chemical properties of organic and conventional sugar-loaf pineapples.
3. To determine the effect of storage in different environment on translucencies and physical parameters of sugar loaf pineapples.

4. To determine the effect of storage conditions on chemical parameters of organic and conventional sugar loaf pineapples.
5. Consumer acceptability studies of sugar loaf pineapples under different storage conditions.

2.0 Methods/ Activities

2.1. Experimental design

Organic and conventional sugar-loaf pineapples were harvested at three different times from Ali farms in Ekumfi area (Central region) and Albe farms in the Eastern Region of Ghana respectively and transported to the CSIR-Food Research Institute.

The summary of the collection data, cultural practices, age of forcing and age of the sugar-loaf organic and conventional pineapples are shown in Appendix 1 and 2. 80- 100 fruits were delivered for each variety per harvesting times.

2.2 Methods

2.2.1 Storage experiments

Organic and conventional sugar loaf pineapples samples were stored at 8° C and 1° C for 2 weeks (14 days). The physical and chemical analysis of the 14 days stored pineapples at 8° C and 1° C were determined. The identified translucencies before storage were <25%, 25-50%. Seven fruits each of conventional and organic pineapples stored at 8° C and 1° C were cut and sliced into chunks for consumer acceptability test.

2.2.2 Physical Parameters

2.2.2.1 Weight of fruits

The fruits were weighed individually using a Laboratory scale (TESTUT platform Scale-NH1200)

2.2.2.2 Weight of Crown

The crown were manually broken and weighed (TESTUT platform scale-NH1200)

2.2.2.3 Crown to fruit Ratio

Crown:Fruit ratio was calculated using the relation:

$$crown\!:fruit = \frac{Weight\ of\ crown}{Weight\ of\ fruit}$$

2.2.2.4 Length of crown

This was measured using a measuring tape. Crown length was measured from the tip of the crown to the point at which the crown touches the fruit.

2.2.2.5 Core diameter

Random samples of fruit were sliced horizontally at the point of the largest diameter and the diameter of the core measure with a ruler.

2.2.3 Chemical analysis

Chemical analysis were carried out on fresh juice extracted from organic or conventional pineapples

2.2.3.1 pH

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).

2.2.3.2 Brix

The brix of pineapple juice was determined using as Abbe Refractometer (Bellingham Stanley Limited, Kent Limited, UK)

2.2.3.3 Total acidity (as % citric acid)

Pineapple juice (25 ml) from each treatment was transferred into 125 ml conical flask. This was titrated against 0.1N NaOH using phenolphthalein indicator. Titratable Acidity was calculated as % citric acid (AACC 2000).

$$\frac{0.007005 \times \text{Titre}}{\text{weight}} \times 100$$

2.2.3.4 Translucency

This was recorded as <25%, 25-50% and 50-75% according to the formation of rings after cutting the pineapple fruit cylindrically

2.2.3.5 Sugar to acid Ratio

This will be determined by dividing the sugar levels of the individual pineapple juice by the acid levels of its corresponding juices from the various treatments.

2.2.3.6 Vitamin C

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

3.0 Results and Discussions

3.1 Baseline characteristics of organic and conventional sugar-loaf pineapple

The baseline physical characteristics of organic and conventional sugar-loaf pineapples for three batches is shown in Table 1. Pineapples can be classified into three categories: category A, defined by fruits weighing more than 1.5 kg; category B, fruits weighing between 1 and 1.5 kg; and category C, fruits weighing less than 1 kg (Infoagro, 2002).

For the first batch of sugar loaf pineapples, the organic pineapples were generally heavier (1.19 kg) than the conventional pineapples (1.16 kg). The difference in weight, however, was not statistically significant ($p \geq 0.05$). The weight of the crown ranged from 0.12-0.16 kg (Table 1) for conventional and organic pineapples respectively. Significant differences existed ($p \leq 0.05$) for the crown weights for organic and conventional pineapples. According to CBI Market Information Database, the average weight of the fruit is 2.5 kg, although there are important variations caused by the plantation density and handling.

Table 1: Baseline physical characteristics of organic and conventional sugar loaf pineapples

Batch 1	Weight of fruits(kg)	Weight of crown(kg)	Crown to fruit ratio	Length of fruit (cm)	Length of crown (cm)	Core diameter (cm)	Translucency
Org	1.19±0.24^{a}	0.16±0.04^{b}	0.15±0.07^{b}	24.78±2.04^{a}	21.32±2.82^{b}	2.29 ±0.19^{a}	26 fruits (25-50%), 4fruits (<25%)
Con	1.16±0.11^{a}	0.12±0.03^{a}	0.11±0.02^{a}	24.38±1.19^{a}	19.04±1.48^{a}	2.26±0.22^{a}	17 fruits (25-50%), 6 fruits (<25%), 6 fruits (50-75%)
Batch 2							
Org	1.13±0.09^{b}	0.12±0.03^{b}	0.14±0.10^{a}	24.41±2.58^{a}	18.17±2.02^{a}	2.19±0.16^{a}	29 fruits (25-50%), 1 fruits (<25%)
Con	1.49±0.16^{a}	0.14±0.03^{a}	0.09±0.02^{a}	26.75±1.44^{a}	20.41±2.15^{a}	2.16±0.22^{a}	2 fruits (25-50%), 28 fruits (50-75%)
Batch 3							
Org	1.07±0.13^{a}	0.16±0.04^{a}	0.16±0.04^{a}	22.58 ± 2.16^{a}	22.70±4.93^{a}	1.97±0.17^{a}	28 fruits (25-50), 2 (<25)
Con	1.22±0.10^{b}	0.16±0.01^{a}	0.16±0.08^{a}	25.42±1.19^{a}	23.10±1.69^{a}	2.02±0.21^{a}	24 fruits (25-50%), 6 fruits (0-25%)

Mean of 30 sugar-loaf pineapples fruits ± standard deviation, Means with the same letters in a row are not significantly different ($P \leq 0.05$). Org = Organic, Con=Conventional

The crown to fruit ratio varied from 0.11 to 0.15 for conventional and organic sugar loaf pineapples respectively. There was significant difference in the crown to fruit ratio at ($p \leq 0.05$) for organic and conventional pineapples. Sugar to acid ratio is an indicator of the acceptability of pineapples. As indicated in Table 1, organic sugar-loaf pineapples were longer than conventional pineapples. Significant differences at ($p \leq 0.05$) was noted for the length of the crown for conventional and organic pineapples. The core diameter was 2.29 cm for organic and 2.26 cm for conventional pineapples (Table 1), with no significant differences ($p \geq 0.05$) between samples. Generally, organic pineapples (86%) recorded a translucency of 25-50%, 13.33% recorded (<25%) translucency. In the conventional pineapples, 56.7% of fruits had a translucency of 25-50%, 20% recorded 50-75% and the remaining were less than 25% translucent (Table 1).

In the second batch, conventional fruits were heavier, with relatively heavier crowns and slightly lower Crown to Fruit, compared to the organic pineapples. The conventional fruits were also longer, had longer crowns and a relatively smaller core diameter. An average core diameter of 2.2 cm was recorded for fruits in both categories. The internal appearance of the flesh is also indicative of fruit maturity. Immature fruits has a white flesh color, while mature or ripe fruit has a yellowishwhite flesh. The flesh also becomes slightly translucent in appearance at maturity. Fruits are over-mature when more than half of the cross-sectional area of the fruit is translucent. Ninety-six (96%) of the organic pineapples gave (25-50%) translucency whiles 3.33% gave (<25%) translucency. For the conventional pineapples, 93.33% recorded (50-75%) translucency and 6.67% (25-50%) translucency. This translucency results indicates that the conventional pineapples are likely to have a shorter shelf-stability.

In the case of the third batch of pineapples, conventional fruits weights was heavier than organic fruits but their crown weights and crown to fruit ratio was the same (Table 1). Conventional fruits and crown lengths was 25.42 cm and 23.10 cm respectively and longer than the organic fruits which recorded 22.58 cm and 22.70 cm for fruits and crown length respectively. Conventional sugar loaf in this batch rather had a larger core diameter, contrary to the trends observed in the previous fruit batches. Whereas 80% of conventional pineapple were 25-50% translucent, more than 90% of organic pineapples fell within this category of translucency. Translucency in the remaining fruits from both groups of pineapple were less than 25%

The baseline chemical characteristics of organic and conventional sugar-loaf pineapples for all three batches of pineapples are summarized in Table 2. As suggested elsewhere (Masniza *et al.,* 2010), this composition may vary with geographical, cultural, seasonal harvesting and processing. Freshly harvested pineapple fruit contains 86% water, 8 g sugars, 0.5 - 1.6 g acids, 1 g proteins, 0.5 g ash, 0.1 g fats, some fibre and vitamins (mainly A and C) .

Table 2: Baseline chemical characteristics of organic and conventional sugar loaf pineapples

	pH	Brix (°)	Titratable acidity (g/100ml)	Sugar to acid ratio	Vitamin C (mg/100ml)
Batch 1					
Organic	3.70 ± 0.10[a]	11.96 ± 1.75[b]	0.71 ± 0.04[b]	16.95	42.85 ± 0.78[b]
Conventional	3.72 ± 0.13[a]	10.95 ± 1.13[a]	0.63 ± 0.08[a]	17.33	31.07 ± 1.37[a]
Batch 2					
Organic	3.68 ± 0.13[a]	13.28 ± 1.57[a]	0.90 ± 0.02[b]	14.79	39.77 ± 1.06[b]
Conventional	3.75 ± 0.14[a]	13.80 ± 1.07[a]	0.72 ± 0.03[a]	19.09	33.70± 0.89[a]
Batch 3					
Organic	3.50 ± 0.09[a]	13.51 ± 1.34[b]	0.95 ± 0.05[a]	14.22	52.06 ± 1.48[b]
Conventional	3.48 ± 0.07[a]	11.96 ± 0.93[a]	0.86 ± 0.08[a]	13.90	37.33 ±1.71[a]

Mean of 30 sugar-loaf pineapples fruits ± standard deviation

The pH (indicator of acidity or alkalinity) of both organic and conventional pineapples was 3.7 in the 1st and 2nd batches. The 3rd batch was slightly more acidic (pH of 3.5) than the previous batches. The pH of conventional sugar-loaf was slightly higher, except for the 3rd batch where a reverse of this trend was observed. The pH values for sugar-loaf obtained in the present study compares well with the pH of 3.71 obtained for pineapples by Masniza *et* al (2008), but was lower than 4.96 suggested for sugar-loaf by Wardy *et al*. (2009). In all 3 batches, acidity of the organic pineapples was significantly higher than the conventional ones. The higher acidity of organic sugar-loaf pineapples may have a positive effect on shelf stability and may be more astringent compared to the conventional type.

With exception of the 2nd batch, brix (ranging from 12.0 – 13.8) for the organic fruits was significantly ($p<0.05$) higher than the conventional fruits (Table 2). °Brix is equivalent to the percentage weight of sucrose; i.e. a solution of 60° brix has 60% sucrose. Pineapple contains 12-15 % sugars of which two-third is in the form of sucrose and the rest are glucose and fructose (Masniza *et al*. 2008). The brix of ripe sugar-loaf generally range between 13.5 and 15% (CBI Market Information Database). Sugar content of pineapple does not increase after harvest. Therefore, fruits must be picked at the optimum maturity and ripeness to suit the intended market. The sugar to acid ratio is a prominent factor for consumer acceptance because it directly influences the taste of fruits. This index was found to be generally higher for the conventional sugar-loaf. Vitamin C was higher in the organic fruits (mean of 44.9 mg/100g), compared to the conventional fruits (34.0mg/100g). Vitamin C is important for its nutritional and health benefits. It ranges between 20 and 65 mg/100g of fresh weight, depending on the cultivar and stage of maturity (Infoagro, 2002). Smith (2005), however suggests a lower range of 10-25 mg/100g.

The titratable acidity (TTA) measures the total acids in the pineapple fruits. The organic sugar-loaf pineapples recorded high titratable acidity compared to the conventional pineapples for all batches with values ranging from 0.63 to 0.95 (Table 2). According to Morton, (1987) and Paul and Chen (2014), an average acid range lies between 0.5 and 1.6 %. The sugar-loaf pineapples recorded acid levels within the range specified by these previous studies.

3.2 Effect of the different storage temperatures on physical and chemical properties of sugar-loaf pineapples

Pineapples harvested at more advanced stages of ripeness will have an abbreviated market life. For example, fruit harvested at the half-yellow color stage will have about 10 days of storage life at 8°C followed by an additional week of market life. Storage of the fruit at 7°C is also necessary to inhibit growth of the fungus. Temperatures of 7 to 12°C are recommended for storage of pineapples for 14 to 20 days provided fruits are at the color break stage (Paull, 1993). A high relative humidity of 85% to 95% is recommended: a high relative humidity significantly reduces water loss. The organic and conventional pineapples were stored at 1°C and 8°C for 14 days. The physical characteristics of organic and conventional sugar loaf pineapples stored for 14 days at 1°C and 8°C for batches 1, 2 and 3 are shown in Table 3.

Table 3: Physical characteristics of organic and conventional pineapples stored at 1° C and 8°C for batches 1 and 2

Batch 1	Weight of fruits (kg)	Weight of crown (kg)	Crown to fruit ratio	Length of fruit (cm)	Length of crown	Core diameter (cm)	Translucency (%)
Org 8°C	1.30±0.13^{a}	0.13±0.03^{a}	0.09±0.03^{a}	25.89±1.26^{a}	20.94±2.52^{a}	2.29±0.21^{a}	15 fruits (25-50%)
Con 8°C	1.09±0.14^{a}	0.12±0.03^{a}	0.11±0.03^{a}	23.95±1.38^{a}	21.11±2.72^{a}	2.17±0.24^{a}	14 fruits (25-50%),1fruit (50-75)
Org 1°C	1.38±0.13^{a}	0.13±0.04^{a}	0.09±0.03^{a}	26.07±1.60^{a}	21.86±3.22^{a}	2.32±0.29^{a}	15 fruits (25-50%)
Con 1°C	1.08±0.16^{a}	0.12±0.03^{a}	0.11±0.03^{a}	23.79±1.79^{a}	20.29±1.76^{a}	2.33±0.29^{a}	11 fruits (25-50%), 4 fruits (50-75%)
Batch 2							
Org 8°C	1.28±0.14^{b}	0.13±0.03^{a}	0.09±0.02^{a}	26.44±1.35^{a}	19.09±2.38^{a}	2.34±0.28^{a}	23 fruits (25-50), 2 fruits (50-75)
Con 8°C	1.50±0.18^{a}	0.13±0.05^{a}	0.09±0.02^{a}	26.73±1.52^{a}	20.00±1.62^{a}	2.54±0.18^{a}	7 fruits (25-50%), 15 fruits (50-75)
Org 1°C	1.38±0.16^{a}	0.11±0.02^{a}	0.08±0.02^{a}	27.59±2.01^{a}	17.85±2.29^{a}	2.31±0.32^{a}	21 fruits (25-50%), 4 fruits (50-75)
Con 1°C	1.40±0.21^{a}	0.10±0.05^{b}	0.07±0.03^{a}	26.05±1.64^{a}	20.37±1.85^{a}	2.50±0.27^{a}	10 fruits (25-50%), 12 fruits (50-75)
Batch 3							
Org 8°C	0.99±0.11^{a}	0.15±0.03^{a}	0.15±0.04^{a}	21.73±3.02^{a}	22.07±1.36^{a}	2.20±0.24^{a}	All 24 fruits (25-50%)
Con 8°C	1.14±0.08^{a}	0.14±0.02^{a}	0.13±0.02^{a}	21.81±0.89^{a}	24.18±1.05^{a}	1.99±0.16^{a}	All 23 fruits (25-50%)
Org 1°C	1.03±0.14^{a}	0.15±0.03^{a}	0.14±0.03^{a}	22.39±4.17^{a}	22.89±1.16^{a}	2.12±0.26^{a}	All 22 fruits (25-50%)
Con	1.13±0.12^{a}	0.14±0.02^{a}	0.13±0.02^{a}	22.12±2.05^{a}	24.67±1.43^{a}	2.13±0.19^{a}	All 23 fruits (25-50%)

Mean of 15 sugar loaf pineapples fruits ± standard deviation

The weight of organic pineapples for batch 1 ranged from 1.3 to 1.38 kg for 8°C and 1°C storage conditions respectively. For conventional pineapples, fruit weight for batch 1 pineapples stored for 8°C and 1°C was 1.09 kg and 1.08 kg respectively. Crown weight ranged from 0.10 to 0.13 kg for all batches for organic and conventional pineapples stored at 1°C and 8°C for 14 days. For batch 1, a translucency of 25-50% was recorded for all the organic fruits, whereas the same translucency was recorded in 93% of conventional sugar-loaf stored at 8°C. Mostly, organic pineapples stored at 1°C presented translucency of 25-50%. Seventy-three percent of the conventional pineapples stored at 1°C had 25-50% translucency while the remaining fruits were 50-75% translucent.

For batch 2 pineapples, majority (92%) of the organic pineapples stored at 8°C were 25-50% translucent and 8% were 50-75% while 84% of those stored at 1°C was 25-50% translucent and the remaining 16% recorded 50-75% translucency. Conventional pineapples stored at 8°C had 32% of pineapples giving a translucency of 25-50% and 68% a translucency of 50-75%. Generally the lower storage temperature (1 °C) resulted in high translucency (50-75%) compared to storage at 8 °C over the 2-week study period. With the exception of changes in translucency, no differences were observed in the physical properties of organic and conventional fruits from the different batches stored at 1°C and 8°C for 14 days.

The dry matter content for the conventional and organic baseline and stored pineapples is given in Table 4. Results indicated that the organic pineapples recorded high dry matter compared to conventional sugarloaf.

Table 4: Dry matter content of organic and sugar loaf pineapples

Condition	Type of pineapples	Dry matter (%)
Baseline	Conventional	12.24 ± 0.51
	Organic	16.44 ± 0.51
Storage at 1°C (14days storage)	Conventional	13.04 ± 0.29
	Organic	14. 53 ± 0.84
Storage at 8°C (14days storage)	Conventional	11.11± 0.14
	Organic	15.66 ± 0.47

Mean of 3 determinations ± standard deviation

Proper storage conditions such as temperature and humidity are needed to lengthen storage life and maintain quality of harvested fruits. Fresh fruits need low temperature and high relative humidity to reduce the respiration and slow down the metabolic process.

The chemical characteristics of the 3 batches of organic and conventional sugar loaf pineapples stored for 14 days at 1°C and 8°C are summarized in Table 5.

Table 5: Chemical characteristics of organic and conventional sugar loaf pineapples stored for 14 days at 1°C and 8°C

Batch 1	pH	Brix	Titratable acidity (g/100ml)	Sugar to acid ratio	Vitamin C (mg/100ml)
Org 8°C	3.49 ± 0.12ᵃ	13.37± 1.39ᵃ	0.62± 0.09ᵃ	17.94	17.93± 2.79ᵇ
Con 8°C	3.38 ± 0.06ᵃ	11.16 ± 1.05ᵃ	0.57± 0.07ᵃ	19.74	21.37 ±2.10ᵃ
Org 1°C	3.50 ± 0.16ᵃ	12.61 ± 1.31ᵃ	0.47± 0.07ᵃ	26.98	10.91 ± 1.45ᵃ
Con 1°C	3.43± 0.09ᵃ	10.84 ± 1.02ᵃ	0.53± 0.02ᵃ	20.36	18.09 ± 1.13a
Batch 2					
Org 8°C	3.44 ± 0.13	13.16± 2.06ᵃ	1.12± 0.04ᵃ	11.73	40.92± 2.05ᵃ
Con 8°C	3.92 ± 0.02	13.10 ± 1.13ᵃ	0.92± 0.11ᵃ	14.30	41.79 ± 0.60ᵃ
Org 1°C	3.96 ± 0.02	13.33 ± 2.05ᵃ	1.05 ± 0.03ᵃ	12.67	43.43 ± 1.64ᵃ
Con 1°C	3.90 ± 0.01	13.70 ± 0.99ᵃ	0.85 ± 0.03ᵃ	16.18	40.86 ± 1.18ᵃ
Batch 3					
Org 8°C	3.55 ± 0.18ᵃ	13.80 ± 1.40ᵃ	1.32 ± 0.11ᵇ	10.45	59.17 ± 2.80ᵃ
Con 8°C	3.93 ± 0.06ᵃ	11.54 ± 1.48ᵃ	1.08 ± 0.08ᵃ	10.69	46.35 ± 1.72ᵇ
Org 1°C	3.98 ± 0.06ᵃ	14.39 ± 1.33ᵃ	1.03 ± 0.05ᵃ	13.97	53.08 ± 2.16ᵃ
Con 1°C	3.96 ± 0.06ᵃ	10.70 ± 2.21ᵃ	0.99 ± 0.03ᵃ	10.80	43.30 ± 2.78ᵃ

Mean of 15 sugar-loaf pineapples fruits ± standard deviation

Generally, storage temperature did not affect the pH of the fruits (either organic or conventional) in storage (Table 5). This indicates that during storage under 1 °C and 8 °C, there was no sign of an initiation of spoilage, which would have resulted in fermentation and subsequent drastic reduction in pH. In the respective fruit batches as well, brix over the storage period was stable, confirming the fact that there was no spoilage during storage. Although the Titratable acidity (TTA) values were largely stable with no significant differences recorded under the different storage temperatures, fruits stored at 1°C apparently gave lower values compared to those stored at 8 °C. Some significant differences were also observed in the Vitamin C content, specifically among the organic fruits under storage. Here, there was a general marked reduction in vitamin C at the lower storage temperature (1 °C). This reflects in the relatively lower TTA values of organic pineapple stored at 1 °C.

3.3 Effect of 14 days storage on the physical and chemical properties of conventional and organic sugar-loaf pineapples

The weight of organic pineapples stored at 1ºC significantly differed ($P<0.05$) from the fruits stored that 8ºC and the baseline (Table 6).

Table 6: Physical characteristics of organic and conventional sugar loaf pineapples at baseline and storage for 14 days at 1°C and 8°C

Batch 1	Weight of fruits (kg)	Weight of crown (kg)	Crown to fruit ratio	Length of fruit (cm)	Length of crown	Core diameter (cm)
Con-Baseline	*1.160.11[A]*	*0.12±0.03[A]*	*0.11±0.02[A]*	*24.4±1.2[A]*	*19.0±1.5[A]*	*2.3±0.2[A]*
1°C	1.08±0.16[A]	0.12±0.02[A]	0.11±0.03[A]	23.8±1.8[A]	20.3±1.8[A]	2.3±0.3[A]
8°C	1.10±0.14[A]	0.12±0.03[A]	0.11±0.03[A]	23.9±1.4[A]	21.1±2.7[A]	2.2±0.2[A]
Org-Baseline	*1.20±0.24[A]*	*0.16±0.04[A]*	*0.15±0.07[A]*	*24.8±2.0[A]*	*21.3±2.8[A]*	*2.3±0.2[A]*
1°C	1.38±0.13	0.13±0.03	0.10±0.03	26.1±1.6[A]	21.9±3.2[A]	2.3±0.3[A]
8°C	1.30±0.13[A]	0.13±0.03	0.10±0.02	25.9±1.3[A]	20.9±2.5[A]	2.3±0.2[A]
Batch 2						
Con-Baseline	*1.49±0.16[A]*	*0.14±0.05[A]*	*0.09±0.02[A]*	*26.8±1.4[A]*	*20.4±2.2[A]*	*2.2±0.2[A]*
1°C	1.40±0.21[A]	0.10±0.03	0.07±0.03	26.0±1.6[A]	20.4±1.9[A]	2.5±0.3[A]
8°C	1.50±0.18[A]	0.13±0.03[A]	0.09±0.02[A]	26.7±1.5[A]	20.0±1.6[A]	2.5±0.2[A]
Org-Baseline	*1.13±0.09[A]*	*0.12±0.03[A]*	*0.14±0.10[A]*	*24.4±2.6[A]*	*18.2±2.0[A]*	*2.2±0.2[A]*
1°C	1.38±0.16	0.11±0.02[A]	0.08±0.02[A]	27.6±2.0[A]	17.9±2.3[A]	2.3±0.3[A]
8°C	1.13±0.13	0.13±0.03[A]	0.10±0.03[A]	26.4±1.3[A]	19.1±2.4[A]	2.3±0.3[A]
Batch 3						
Con-Baseline	*1.22±0.10[A]*	*0.16±0.02[A]*	*0.16±0.07[A]*	*25.4±1.2[a]*	*23.1±1.7[A]*	*2.0±0.2[A]*
1°C	1.13±0.12	0.14±0.02	0.13±0.02[A]	22.1±2.1[a]	24.7±1.4[A]	2.1±0.2[A]
8°C	1.14±0.08	0.14±0.02	0.13±0.02[A]	21.8±1.9[b]	24.2±1.1[A]	2.0±0.2[A]
Org-Baseline	*1.07±0.13[A]*	*0.16±0.04[A]*	*0.16±0.04[A]*	*22.6±2.2[a]*	*22.7±4.9[A]*	*2.0±0.2[A]*
1°C	1.03±0.13[A]	0.15±0.03[A]	0.15±0.03[A]	22.4±4.2[a]	22.9±1.2[A]	2.1±0.3[A]
8°C	0.99±0.11	0.15±0.03[A]	0.15±0.04[A]	21.7±3.0[a]	22.1±1.4[A]	2.2±0.2[A]

Means not labeled with the letter A are significantly different from the control level mean (Dunnett's Test). Baseline values served as control

This trend was observed as the weights of the pineapples was 1.20 kg at the baseline studies and 1.30 kg at 8ºC storage and 1.38 kg at 1ºC. Comparatively, lower weights of fruits were generally measured in the case of the conventional pineapples. As the weights of the organic pineapples increased with lower temperatures, weights of conventional pineapples decreased indicating that at reduced temperatures, the cell membranes of the conventional pineapples had become compacted and rigid making it difficult to imbibe water molecules hence the reduced weights.

In the second batch of the analysis, relatively higher fruit weights were measured in the conventional pineapples compared to the organic ones. There was significant difference ($P \leq 0.05$) in the weights of the organic pineapples with respect to low temperatures. The initial weights of the organic pineapples were same (1.13 kg) at the baseline and at 8º but increased steadily to 1.38 kg at 1 ºC. There was however no difference in the weights of the conventional pineapples.

In the case of the weights of the crown, significantly differences were measured in the organic pineapples while no difference was observed among the conventional pineapples. Comparatively, lower weights of 0.12 kg were measured in the conventional pineapples with much higher crown weights (0.13 - 0.16 kg) in the organic pineapples. In the second batch of the analysis, there was no difference in the weights of the crown among the organic samples whereas significant difference ($p<0.05$) was measured at the lowest temperature (1 ºC) with respect to the conventional ones.

The crown to fruit ratios recorded in the organic pineapples were significantly different ($P\leq0.05$) while those recorded among the conventional pineapples were same. Averagely lower crown to fruits ratios were measured among the organic pineapples whereas higher ratios were recorded in the conventional pineapples in the second batch of the analysis. There were differences in the ratios measured in the second batch of the organic pineapples. This can be directly linked to varietal difference existing between the two species of the pineapples.

There was significantly no difference ($p>0.05$) in the length of fruits without peduncle with respect to both organic and the conventional pineapples. Relatively higher fruit length was observed among the organic pineapples compared to those of the conventional ones. The same trend was observed in the second batch of the analysis.

The ANOVA analysis of the length of crown showed significant difference ($p<0.05$) among the organic pineapples. Significantly lower length of crown values were measured among the organic pineapples at lower temperatures (1 ºC and 8 ºC) whereas no significant differences were measured in the conventional pineapples. In the second batch of the analysis, no significant differences were measured in both the organic and the conventional.

Temperature had no significant difference on the core diameters of both organic and conventional pineapples in the first and second batch of the analysis. The core diameter averagely ranged from 2.2 to 2.30 among the organic pineapples whereas that of the conventional ones was in the range of 2.2 to 2.5.

Decreasing temperatures significantly increased ($p<0.05$) the brix content of the organic pineapples whereas there was no significant difference in the conventional pineapples. This indicates that at lower temperature the sucrose content in the pineapples was on ascendancy since brix is an indicator of the sucrose content in the fruits.

The highest brix content recorded in the organic pineapples was obtained at 8ºC (Table 7). This confirms the assertion that organic pineapples are naturally sweeter than the conventional ones. One can deduce that at freezing (8 ºC) and near chilling (1 ºC) temperatures, there was retention of sugars in the organic pineapples. Varietal difference and treatment prior to planting of the pineapples influenced the differences in the brix content of both the organic and conventional pineapples. In reference to the second batch of the analysis, there was significantly no difference in the brix contents between the two types of the pineapples.

Table 7: Chemical characteristics of organic and conventional sugar loaf pineapples at baseline and storage for 14 days at 1°C and 8°C

Batch 1	Brix	pH	Titratable acidity (g/100ml)	Sugar to acid ratio	Vitamin C (mg/100ml)
Con-Baseline	$11.0±1.1^A$	$3.73±0.16^A$	$0.63±0.08^A$	17.33	$19.701.37^A$
1°C	$10.8±1.0^A$	3.47±0.12	$0.53±0.02^A$	20.36	11.47±1.13
8°C	$11.2±1.1^A$	3.36±0.07	$0.57±0.07^A$	19.74	13.55±2.10
Org-Baseline	$12.0±1.8^A$	$3.70±0.10^A$	$0.70±0.04^A$	16.95	$27.170.78^A$
1°C	$12.6±1.3^A$	3.50±0.16	0.47±0.07	26.98	6.92±1.45
8°C	13.4±1.4	3.50±0.12	$0.62±0.09^A$	17.94	11.37±1.79
Batch 2					
Con-Baseline	$13.8±1.07^A$	$2.66±0.23^A$	$0.72±0.03^A$	19.09	$21.37±0.89^A$
1°C	$13.7±0.99^A$	$2.62±0.10^A$	0.85±0.03	16.18	25.91±1.17
8°C	$13.1±1.12^A$	2.46±0.11	0.92±0.11	14.30	26.50±0.61
Org-Baseline	$13.3±1.6^A$	$2.62±0.17^A$	$0.90±0.02^A$	*14.79*	$25.22±1.06^A$
1°C	$13.3±2.0^A$	$2.62±0.09^A$	1.05±0.03	12.67	$27.54±1.65^A$
8°C	$13.2±2.1^A$	2.41±0.08	1.12±0.04	11.73	$25.95±2.05^A$
Batch 3					
Con-Baseline	$12.0±0.9^A$	$3.48±0.07^A$	$0.86±0.08^A$	13.90	$23.66±1.71^A$
1°C	10.7±2.2	3.96±0.06	0.99±0.03	10.80	27.46±2.78
8°C	$11.5±1.5^A$	3.93±0.06	1.08±0.08	10.69	29.39±1.72
Org-Baseline	$14.4±1.3^A$	$3.50±0.09^A$	$0.95±0.05^A$	*14.22*	$33.02±1.48^A$
1°C	13.8±1.4	3.98±0.06	$1.03±0.05^A$	13.97	$33.66±2.16^A$
8°C	$13.5±1.3^A$	$3.55±0.18^A$	1.32±0.11	10.45	37.52±2.80

Means not labeled with the letter A are significantly different from the control level mean (Dunnett's Test). Baseline results served as control.

With reference to the ANOVA analysis of the pH, there were significant differences ($P \leq 0.05$) in the pH of the two species of the pineapples across the temperature gradient. Although the results showed that all pineapples samples were in the acidic range of 3.36 to 3.70, the trend clearly describes constant drop in pH with decrease in temperature. It can be inferred that the low temperature medium of storage encouraged the formation of low acidic state of the two pineapple types under study. In effect, the organic pineapples were narrowly acidic than the conventional ones. In the case of the second batch of the analysis, comparatively lower pH values were measured in all pineapple samples (both organic and conventional).

The storage temperature gradient, varietal difference and treatment conditions prior to that cultivation of the two types of the pineapples had significant influence on the Vitamin C content of the pineapples. Relatively higher Vitamin C content was measured in the organic pineapples compared to that of the conventional ones. The vitamin C content of the organic pineapples were in the range of 6.92 to 27.17 whereas that of the conventional lied in the range of 11.47 to 19.70. The trend revealed that there was a reasonably steady decrease in vitamin C content with respect to decrease in temperature gradient among the organic pineapples. Similar trend was observed in the case of the conventional pineapples.

4.0 Conclusions

Organic sugar-loaf pineapples were larger compared to conventional pineapples. . The dry-matter content for the organic sugarloaf pineapples were higher than the conventional.

Generally, conventionally stored sugar- loaf pineapples at 8°C attained a higher translucency (50-75%). More spoilage (12%) was observed for the conventionally stored pineapples stored at 8°C.

Translucency (25-50%) was observed for organic sugar loaf pineapples stored at 8°C. Only 8% of the fruits recorded 50-75% translucency. This translucency results indicates that the conventional pineapples will have a shorter shelf-stability than organic pineapples.

The organic sugar loaf pineapples stored at 1°C, had 50-75% translucency (16%), the rest had 25-50%. Conventionally stored sugar loaf pineapples (52.3%) at 1°C recorded 50-75% translucency. A direct relationship was observed between titratable acidity and vitamin C

Vitamin C content and total titratable acidity of the sugar-loaf pineapple (both organic and conventional) reduced in storage (8°C and 1°C) over the 14-day period.

Based on the result so far, it can be concluded that organic pineapples could be sea freighted using the storage temperatures of 8°C and 1°C within 14 days, if proper handling, packaging and storage conditions are adhered to.

4.1 Recommendation

1. Information on the maturity of the pineapples, days of count, and cultural practices of the farmer and the age of forcing should be made available before the storing. This will help assess the storage process effectively.

2. More trails should be done to come to a logical conclusion on the possibility of sea freighting organic sugar loaf pineapples.

3. There is a need to ensure that the sugarloaf pineapples being exported is really organic in the first place.

4. The pH, brix value and vitamin c levels of the stored pineapples must be monitored at two to three days intervals till the 14 days to adequately understand the trend.

5. The glucose, fructose and sucrose of sugar loaf pineapples must be determined during storage.

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Appendix 1

The table 1 below gives a brief data on **certified organic** pineapple farm collection in Ali farms at Essueshia in the central region of Ghana from April 21st to June 21st, 2017.

Appendix 1.1 Summary of Collection Data

DATE OF COLLECTION	No. OF PINEAPPLE PER BOX	TOTAL QTY COLLECTED	CULTURAL PRACTICES	AGE OF PINEAPPLE AT COLLECTION	AGE FORCING
21st April, 2017	**8**	**80 pieces**	• Weed control (hoeing) at every three months • Forcing at 11th month using ethylene Gas	**135 days**	**11 months**
16th May, 2017	**8 and 9**	**100 pieces**			
21st June, 2017	**8 and 9**	**100 pieces**			
Total quantity of pineapples collected		**280 pieces**			

Appendix 1.2: Data Collecton on *Conventional* Pineapple from Albe Farms, Eastern Region from April to June 2017

DATE OF COLLECTION	NO OF PINEAPPLE PER BOX	TOTAL QUANTITY COLLECTED	CULTURAL PRACTICES	AGE OF PINEAPPLE AT COLLECTION	AGE AT FORCING
21st April 2017	8	80	• Sorting and grading of pineapple suckers for planting • Land preparation (Ploughing and harrowing • Planting of suckers • Application of fungicides Alliette (3days after planting • Application of root developer and insecticides Desban (2weeks after planting) • Fertilizer application • Weedicide application, Gallant and Diuron (3months) • Fertilizer, Urea and insecticide application (6times before harvest) • Manual weeding • Forcing (8months) • Harvesting	150 days	8 months
16th May 2017	8 and 9	100		150 days	8 months
21st June 2017	8 and 9	100		150 days	8 months