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Nutritional characterization of organically and conventionally grown mango (*Mangifera indica* L.) and pineapple (*Ananas cosmus*) of different origins

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Horticulture in Tanzania has become a very important sector because the demand for organically produced tropical fruits has dramatically increased worldwide. In this study, organically and conventionally grown mango and pineapple from different origins were analysed for nutritional variables. Characterization of fruit derivatives was achieved using several variables, namely fruits size and colour, º brix (measurement for the sugar concentration of liquids), titratable acidity, pH, organic acids, free sugars, and minerals. Fruit samples analyzed were: fresh organic mangoes local cultivars *'Dodo', 'Bolibo', 'Viringe'*, cultivar *'Tommy Atkins'* and conventionally produced cultivars *'Kent'*, organic and conventional pineapple cultivars *'Smooth cayenne'*. The cultivars and their type of cultivations have shown an influence on the levels of titratable acidity, organic acids, sugars and mineral contents like calcium, potassium, magnesium and manganese. Titratable acidity was higher in organic than conventional mango cultivars. Fructose and glucose contents were 22 and 28% higher in conventional than in organically produced mango fruits, respectively. Conventional pineapple fruits have shown higher fructose and glucose content by 18 and 10% as compared with organic pineapple fruits. Malic and citric acids levels were 30 and 16% higher in conventional than organically grown mango cultivars. Manganese, calcium and magnesium contents were 33, 18 and 12% in organic than conventionally grown pineapple fruit. Organic mango cultivars were shown to have higher contents of phosphorus and potassium by 17 and 6%.

Key words: Mango, pineapple, organic cultivation, nutritional variables.

INTRODUCTION

The quality of fruit varies to a large extent due to differences in terms of their taste, flavour, colour, aroma and size. Normally, on purchasing fruits, consumers consider external appearance such as freedom from external damage, weight, colour and consistency. Ruben et al. (2005) stated that these quality variables are considered in crop management and post-harvest technologies. Mango (*Mangifera indica* L.) and Pineapple (*Ananas cosmus*) are among the most important popular and best known tropical fruits. Acceptable colour and flavour with high contents of nutrients are important features in selecting mango and pineapple fruit cultivars for processing. Forney et al. (2000) found that chemical

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composition could be influenced by geographical location, horticulture practice, season and cultivar.

Minerals play a major role in human nutrition and they are important for the maintenance of human health (Frossard et al., 2000). For example, iron is a major component of the blood component haemoglobin and involved in the electron transfer system of enzymes. A deficiency of iron may lead to fatigue, headache and sore tongue in addition to anaemia. Calcium is important in bone formation and zinc is essential for protein and nucleic acid synthesis, carbohydrate metabolism, successful pregnancy, delivery and normal physiological development of the infant. Magnesium is involved in most phosphate transfer reactions, the structural stability of nucleic acids and the intestinal absorption of nutrients. In most developing countries, mineral deficiency, especially that of iron, is still a public health issue probably due to the over-dependence on plant food sources (Frossard et al., 2000).

During the peak harvesting season, fresh fruit faces problems in sustaining for a lengthy period. Rough handling of fruit may result in damage of plant cellular structure, which plays a protective role for the texture of the fruit. This may lead to moisture loss and accelerates enzyme activities that cause browning (Taylor and Olivas, 2007). As a result, there is an increased susceptibility to microbial spoilage, discolouration and respiration, and finally fruit loses its quality. It is thus important to be aware of the nutritional quality of fruits during their shelf life periods and the influences of agricultural practice, geographical location and type of cultivars on quality variables. The main objective of the studies was to evaluate some of the quality attributes of fresh mango and pineapple fruit by evaluating the following variables: weight, colour, total soluble solids, sugar, minerals, titratable acidity and organic acids. The hypothesis being tested was that agricultural practice, geographical location and type of cultivars could significantly influence variation in quality.

MATERIALS AND METHODS

The study covered organically and conventional grown fruit cultivars of mango and pineapple. Organically grown mango (*Mangifera indiga* L. *cv. Dodo, Bolibo*, *Viringe*) and pineapple (*Ananas comosus* L. *cv. Sooth cayenne*) from Tanzania were obtained from local markets in Dar es Salaam, Tanzania, and transported by airplane to Germany. Fruit obtained from shops in Göttingen, Germany, were organic mango *cv. Tommy Atkins* from Burkina Faso, conventional mango *cv. Kent* from the Ivory Coast, Mali, Peru and Costa Rica, organic pineapple *cv. Smooth cayenne* from Uganda and conventional pineapple cv. *Smooth cayenne* from Ghana and Honduras. All samples were obtained between January and March in 2006, 2007 and 2008 and analysed in the Laboratory, Section of Quality Plant Products, Department of Crop Science at the University of Goettingen, Germany. Five individual samples at a similar stage of ripeness were obtained. After removing the non-edible parts, the samples were cut into small pieces and frozen. The samples were freeze-dried prior to determination of mineral content, sugar, organic acids and dry matter content. Fresh fruit juices were used for the determination of pH, pulp colour, titratable acidity, total soluble solids and total sensory evaluation. The fruits were stored at Temperature of 13°C, Humidity of 95% and the moisture content of fruits was on the average (88%).

Pulp colour measurement

Objective colour measurements were made using a Minolta Chroma Meter CIE 1976 (model CR-200, Minolta Corp., Ramsey, NJ) calibrated with a white plate. CIE refers to the Commission Internationale de l'Eclairage (International Commission on Illumination) (McGuire, 1992). Colour was expressed as CIELAB (L*a*b*) colour space, where L* defines the lightness and a* and b* define the red-greenness and blue-yellowness, respectively. The more representative colour variables are included in the results. In all cases, five pieces per replicate were used.

Sensory evaluation

The sensory test helps to understand the attributes of a product from a consumer's point of view, which is critical to its acceptance. The sensory quality of organic fruit juices, mango cultivar *'Dodo'* and pineapple cultivar *'Smooth cayenne'* from Tanzania were evaluated (overall quality, colour, texture and aroma) by 11 untrained and randomly chosen panelists. For overall quality and colour, the scale was 1-9 (hedonic scale) as described by Meilgaard et al. (2000). Panel test procedures were performed at room temperature. A panel of eleven judges scored the taste of juice. Like extremely = 9, Like very much = 8, Like moderately = 7, Like slightly = 6, Neither like nor dislike = 5, Dislike slightly = 4, Dislike moderately = 3, Dislike very much = 2, Dislike extremely = 1.

Determination of titratable acidity, pH, and total soluble solids

Juice samples were obtained by squeezing half of the fruit slices from each replicate with a hand juicer. Total soluble solids content (ºBrix) of the juice was measured with an Abbe Refractometer, model 10450 (American Optical, Buffalo, NY), and expressed as a percentage. To measure the pH and titratable acidity (TA), a 3-5 ml juice sample per replicate was diluted with 20 ml of distilled water and titrated with 0.1 N NaOH to pH 8.1. TA was calculated as percent of anhydrous citric acid as the predominant acid (AOAC, 1998).

Determination of sugars

Carbohydrate analysis fractions were extracted as described by Keutgen (2000). 100 mg of dried fruits samples with 10 mL of distilled water were heated for 60 min in a water bath at 60°C and centrifuged for 20 min at 10,000 rpm. Glucose, fructose, and sucrose were determined from the membrane filtrated supernatant (diameter 0.45 µm). These carbohydrates were determined by injection of 20 µL samples volume into an HPCL system using a LiChrospher 100 NH2 (5 µm) 4 × 4 mm pre-column (No. 1.50966.0001, Merck KGaA, Darmstadt, Germany) in combination with a LiChrospher 100 NH2 4 x 250 mm separation column (No. 1.50834.0001, Merck KGaA, Darmstadt, Germany). The column temperature of 20°C was controlled by the column thermostat Jetstream 2 (Knauer, Berlin, Germany). An acetonitrile: pure water solution (80:20 v/v) was used as mobile phase (flow rate 1.0 ml min^{-1}). A Knauer differential refractometer 198.00 (Knauer, Berlin; Germany) was used to detect carbohydrates contents in the fruit samples and their concentrations were calculated according to the method of Keutgen (2000). The sum of glucose, fructose, and sucrose was considered as a measure of soluble carbohydrates. The results were expressed in % of dry matter.

Determination of organic acids

For measurement, the samples were prepared as described for carbohydrates. This determination was modified after Neumann according to the method of Mentasti et al. (1985), Keefer and Schuster (1986) and Szmigielska et al. (1997). The protonated organic acids (pH of eluent = 2.2) was separated by hydrophobic interactions with the apolar stationary phase of the reversed phase column. The HPLC consists of an Inline Degaser (Water, Germany), a Maxi Star, K 1000 HPLC pump (Knauer, Germany), a LKB autosampler 2157 (Pharmacia, Germany), a UV/VIS - Photodiodenarray Detector 996 (Waters, Germany), a Multi - Eluents support system Water 6000E Powerline and a Millennium data acquisition system (Waters, Germany). Organic acids were separated with 250 × 4 mm Lichrospher-100 5 µ RP-18 column with a guard column (Merck, Germany) at a flow rate of 0.5 ml/min and a temperature of 20°C. 18 $mMKH_2PO_4$ water solution (pH 2.2) as isocratic solution was used as eluent. The concentration of the organic acids was detected at 210 nm (sample volume 20 µl). The results were expressed in % of dry matter.

Mineral content

Macro and micronutrients determination in the samples were carried out according to the procedure used by Abu-Samra et al. (1975) and Pardede (2004). 400 mg materials were weighed in a special plastic vessel resistant to heat and acid (MPV 100, Germany) with 4 ml nitric acid (65%) was added. After being covered, the samples were tightly closed in a special metal holder and heated up at 175°C for 12 h in an oven (Memmert GmbH - Germany). The resulting solutions were analyzed for magnesium (Mg) and iron (Fe) using AAS (atomic absorption spectroscopy) from Perkin-Elmer (USA), potassium (K) and calcium (Ca) using FES (Flame Emission Spectrometer, Elex 6361) from Eppendorf - Germany and phosphorus (P) using Spectrophotometer (Hewlett Packard 8453, Germany) following the P-yellow method on P (Wilhelm et al., 1983).

Statistical analysis

The generated data were entered into a spread sheet and imported into SigmaStat program version 2, where various statistical tests were performed using ANOVA. A least significant different (LSD) test, a multiple comparison test, was performed in an attempt to discern if significant differences existed between the sample means.

RESULTS AND DISCUSSION

Size and colour measurement

A number of variables related to fruit quality were evaluated in order to characterize the samples. The mean weight of the mangoes ranged from approximately 500 to 700 g, being classified from medium to large. These sizes meet the market requirements for fresh mango consumption (Carvalho et al., 2004). Pineapple weight ranged between 1.4 to 1.8 kg. The fruit circumference in length and width are shown in Table 1. In the fruits and vegetables, water represents the highest percentage of total weight. The maximum amount varies among fruits of the same kind due to their structural differences (Hanafi

Table 1. Fruit weight, length and width circumference of mango and pineapple fruits.

Fruit	Fruit weight (g)	Length circ. (cm)	Width circ. (cm)	Origin	Production
Mango cultivars					
Dodo	578.0±73.2bc	30.3±4.66c	25.9±6.77b	Tanzania	O
Bolibo	686.3±53.9a	35.8±2.14a	30.7±1.97a	Tanzania	O
Viringe	329.3±23.2e	27.0±0.76d	25.8±0.75b	Tanzania	O
Tommy Atkins	506.9±19.8bcd	32.2±1.44bc	29.8±1.48ab	Burkina Faso	O
Kent	449.4±23.3d	31.5±0.84c	25.8±6.88b	Costa Rica	C
Kent	478.7±46.3cd	31.2±1.82c	29.6±0.96ab	Ivory Coast	C
Kent	581.1±15.8b	35.4±1.39ab	29.6±1.19ab	Mali	C
Kent	591.2±88.7b	32.9±1.24bc	30.7±1.60a	Peru	C
Pineapple cultivar					
Smooth cayenne	1720.5±34.2a	40.8±10.8b	38.9±1.09a	Tanzania	O
Smooth cayenne	1119.0±34.5b	40.0±3.46b	38.6±3.75a	Uganda	O
Smooth cayenne	2010.8±54.8a	54.0±3.46a	42.3±1.15a	Costa Rica	C
Smooth cayenne	1904.4±49.3a	52.5±2.55a	40.9±1.34a	Ghana	C
Smooth cayenne	1147.2±98.5b	39.4±0.80b	35.5±1.56a	Honduras	C

Values within columns with different letters are significantly different ($p \leq 0.05$).
Abbreviations: O=organic and C=conventional.
The determination of the coordinates L*, a*, b* characterizes pulp colour. At this scale, L* measures luminosity that varies from zero (black) to 100 (pure white); a*and b* values represent the levels of tonality and saturation, with + a (indicating red), - a (indicating green), + b (indicating yellow) and - b (indicating blue). Positive values of a* and b* as observed are attributed to the carotenoids present in the pulp.

et al., 2009). The effect of plantation management could influence the structural differentiation. A reduction in fruit weight, can cause fruit shrivelling and advance senescence. In most cases, this is dependent on the relative humidity surrounding the fruit and also could be associated with a slight reduction in flesh firmness (Nock, 2012). Normally, the weight loss could be due to the rates of respiration and transpiration of water, which could be attributed to biological changes taking place during storage.

The colour of fruit pulp is shown in Table 2. Slight differences were found for ‘L’, ‘a’ and ‘b’ parameters. L values in mangoes ranged between 43.16 and 88.99, Dodo cultivars from Tanzania had the lowest L value as compared with other mango cultivars. Pineapples are lower in b values indicating less yellow colour. The findings indicated higher values of yellowness (*b* values) observed in the mangoes, which could be associated with an increase in carotenoids due to the ripening process. Mendes-Pinto (2009) reported that the production of carotenoids increases during the ripening of mango fruits.

Sensory evaluation

The sensory evaluation of organic fruits juice of mango cultivar *‘Dodo’* and pineapple cultivar ‘*Smooth cayenne’* collected from Tanzania was done to assess the acceptability to consumers. Mango cultivar *‘Dodo’* is very popular for juice making due to its short shelf life period. Pineapple cultivar *‘Smooth cayenne’,* during peak periods, tends to mature in bulk. Due to its high perishability, post-harvest technology plays a major role for its human nutrition suitability. The quality assessment and duration of post-harvest life of fruit are important for the management of fresh products during the distribution chain, especially from distribution points to markets.

The results of the sensory evaluation of mango and pineapple juices are shown in Table 3. Differences in the acceptability of the overall quality of the fruit juices were observed during the sensory evaluation. Mango juice was mostly preferred as compared with pineapple juice due to the taste. The taste of pineapple juice scored less, because pineapple juice tastes bitter when compared with mango juices. The important attributes for sensory evaluation are level of sugar, salt, titratable acid and bitter compounds such as alkaloids. These contribute significantly to taste. The sensory characteristics of fruit have been correlated to the levels of sugars and organic acids and their ratios (Colaric et al., 2005).

The quality attributes for mango and pineapple fruits are shown in Table 4. Pineapple was shown to have 30% higher citric acid content when compared with mango, which contributed to the bitter taste of pineapple juices.

Table 2. Pulp colour in mango and pineapple fruits.

Fruit	L	A	B	Origin	Production
Mango cultivars					
Dodo	43.16±2.38c	-3.39±2.59a	44.88±27.82ab	Tanzania	O
Bolibo	73.27±5.42b	-4.60±7.35b	48.36±13.27ab	Tanzania	O
Viringe	81.09±2.97ab	-6.66±4.43b	69.45±11.30a	Tanzania	O
Tommy Atkins	80.29±1.86b	-5.79±2.85b	61.19±3.10a	Burkina Faso	O
Kent	88.99±1.21a	-4.62±5.55b	39.06±28.20b	Costa Rica	C
Kent	80.89±0.98ab	-9.08±3.16b	72.79±24.15a	Ivory Coast	C
Kent	81.98±1.23ab	-8.84±2.35b	66.97±4.08a	Mali	C
Kent	77.09±3.52b	-5.52±4.45b	73.57±5.40a	Peru	C
Pineapple cultivar					
Smooth cayenne	55.66±1.28c	-3.50±0.41a	27.27±0.97c	Tanzania	O
Smooth cayenne	80.26±3.24a	-10.29±0.35bc	48.47±3.50b	Uganda	O
Smooth cayenne	79.85±1.00a	-10.24±0.47a	54.57±3.45a	Costa Rica	C
Smooth cayenne	78.23±2.48a	-9.26±0.42abc	46.40±2.87b	Ghana	C
Smooth cayenne	73.17±5.16b	-2.39±6.29ab	29.52±35.25a	Honduras	C

Values within columns of the same fruits with different letters are significantly different ($p \leq 0.05$).

Table 3. Sensory analysis of mango and pineapple juices from Tanzania.

Parameter	Mango juice	Pineapple juice
Appearance	6.88±2.03a	6.25±2.96a
Aroma	6.25±2.18a	5.38±2.72a
Taste	5.88±1.56ab	3.37±2.56b
Density	5.25±2.18b	5.00±1.85b
Overall	5.88±1.72	3.87±2.69

Values within columns of the same fruit juice with different letters are significantly different ($p \leq 0.05$).

Table 4. Quality attributes of mango and pineapple fruits from Tanzania.

Attributes	Units	Mango cultivar. *'Dodo'*	Pineapple cultivar. *' Smooth cayenne'*
TSS	°Brix	14.2	15.1
Fructose	mg 100g $^{-1}$ FW	2.26	2.19
Glucose	mg 100g $^{-1}$ FW	1.35	2.12
Sucrose	mg 100g $^{-1}$ FW	5.00	7.14
Taste	Score	5.88	3.37
Titratable Acidity	(%)	1.89	1.52
pH		3.63	3.79
Malic Acid	mg 100g $^{-1}$ FW	0.74	0.12
Citric Acid	mg 100g $^{-1}$ FW	0.30	0.43
Sugar/Acid ratio		6.76	9.70

Malundo et al. (2001) showed that in sensory and chemical evaluations of fruits, the individual sugars and organic acids, as well as their ratio, could be crucial in determining the taste. The organic acids play an

Table 5. Titratable acidity (TA) in citric acid, pH, malic acid (MA) in and citric acid (CA) in mango and pineapple fruits.

Fruit	TA(%)	pH	MA (mg $100g^{-1}$ FW)	CA (mg $100g^{-1}$ FW)	Origin	Production
Mango cultivars						
Dodo	1.89±1.01abc	3.63±0.11bc	0.74±0.43c	0.32±0.12ab	Tanzania	O
Bolibo	2.31±0.24ab	3.62±0.03bc	0.84±0.08bc	0.26±0.06abc	Tanzania	O
Viringe	2.37±0.08a	3.53±0.08bc	1.24±0.11ab	0.21±0.09c	Tanzania	O
Tommy Atkins	1.25±0.06bc	3.63±0.10bc	1.61±0.09a	0.20±0.03c	Burkina Faso	O
Kent	1.03±0.15c	3.70±0.09ab	0.84±0.16bc	0.24±0.03bc	Costa Rica	C
Kent	1.43±0.11abc	3.50±0.20c	1.34±0.22ab	0.31±0.12abc	Ivory Coast	C
Kent	1.12±0.08c	3.63±0.12bc	1.67±0.14abc	0.38±0.16a	Mali	C
Kent	1.31±0.04abc	3.85±0.13a	1.34±0.48ab	0.36±0.11ab	Peru	C
Pineapple cultivar						
Smooth cayenne	1.52±0.53b	3.79±0.21ab	0.12±0.03b	0.43±0.15a	Tanzania	O
Smooth cayenne	2.23±0.09a	3.30±0.20c	0.08±0.01c	0.38±0.01ab	Uganda	O
Smooth cayenne	1.69±0.27ab	3.62±0.11b	0.18±0.08a	0.32±0.08c	Costa Rica	C
Smooth cayenne	2.35±0.18a	3.63±0.06b	0.11±0.01bc	0.38±0.03ab	Ghana	C
Smooth cayenne	1.00±0.20b	4.03±0.06a	0.13±0.04b	0.29±0.09bc	Honduras	C

Values within columns of the same fruits with different letters are significantly different ($p \leq 0.05$).

important role in fruit taste through the sugar/acid ratio. Although pineapple showed a 30% higher sugar to acid ratio as compared with mango, panelists scored less for pineapple when compared with mango. Sugar provides sweetness and the organic acids sourness. The main organic acids present in fruits are citric and malic acids (Karadeniz, 2004). In fruit, the content of sugar and organic acid accounts for sweetness and acidity (Malundo et al.,2001). Kim et al. (2015) found the taste of fruit was influenced by the balance between organic acids and soluble sugars, mainly citric acid and malic acids, fructose and glucose, respectively.

Titratable acidity, pH, and organic acids

The ratio H+/ acidity could be used as an index of maturity. The acidity may be useful as a reference to the stage of maturity or as objective information related to flavour. Therefore, a fruit with a lower acidity would have a sweeter flavour. Changes in pH are associated with the acid content, which changes during the development, and consequently low pH (2.0 - 4.0) values indicate high acid concentrations. Titratable acidity is directly related to the concentration of organic acids present in the fruits. Organic acids, mainly citric acid and malic acid, together with sugar contribution of fructose and glucose lead to their mutual action, which derives the sweetness and sourness of fruits (Degree et al., 2012). Fruit quality is one of the several criteria to be considered in making some industrial products, for example, organic acids contents in fruits, fruit chemical compounds, types of sugar contents, pigment and many others. These variables have played a major role in improving the quality of the products (Degree et al., 2012). The high concentration of acid in ripe fruit may not only influence palatability and flavour of the derived products, but it may also affect the suitability for specific uses (Sha et al., 2011). It is commonly known that different types of fruit contain different amounts of organic acids due to the fact that edible fruits are used as food acidulates in manufacturing beverages and drinking juices. Some organic acids in ripe fruits may influence the sensory properties of the derived products, even though they may be considered as minor components (Sha et al., 2011). When they are present in combination with sugars, they could possibly be an important influence on the sensory quality of both raw and processed fruits (Turhan and Seniz, 2009). Organic acids, such as citric, malic, oxalic, ascorbic and tartaric acids. could influence the flavour at the ripe stage (Shui and Leong, 2002). The organic acids as an important fruit component for making juices and beverages and their ratios could determine the percentage of juice content (Malundo et al, 2001).

In Table 5, the mango cultivars show significant variation ($p \leq 0.05$) in their titratable acidity percentage. There were significant variations in their titratable acidity among the mango cultivar *'Kent'* grown under a

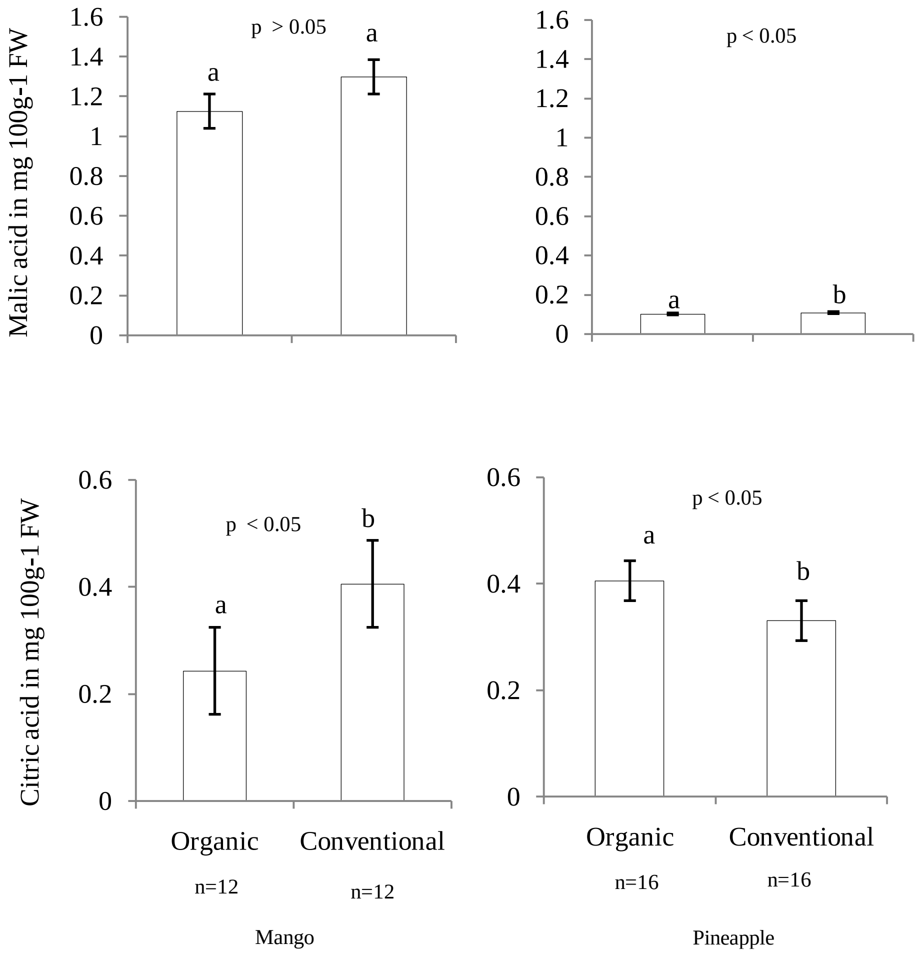

Figure 1. Organic acids (mg $100g^{-1}$ FW) in conventional and organic in mango (n=12) and pineapple fruits (n=16). Values with different letters are significantly different ($p \leq 0.05$).

conventional production system in different locations, which shows an effect of location on titratable acidity levels among the fruits. Mango cultivar '*Bolibo'* and '*Viringe*' was shown higher titratable acidity than other cultivars and a value 54% higher in organic than conventional fruit.

The pH values ranged between 3.50 and 3.85 whereby the mango cultivar *'Kent'* showed higher pH value of 3.85 as compared with other mango cultivars. Mango cultivar *'Kent'* is normally harvested while green and unripe, which leads to higher citric acid levels than cultivars harvested later. The pH level was 1.9% higher in conventional as compared with organic, indicating the sensitivity of pH level in mango.

Malic acid levels varied significantly ($p \leq 0.05$) within the mango cultivars and it was found to be higher in *'Kent'* and 'Tommy *Atkins*'. Malic acid levels were 19.7% higher in mango cultivars under conventional than organic.

Citric acid levels were significantly different ($p \leq 0.05$) with cultivar *'Kent'* and higher in some locations than others. Citric acid levels were 13.9% higher in mango cultivars produced in conventional than organic.

The pineapple cultivar *'Smooth cayenne'* showed significant variation between conventional and organic production systems. Titratable acidity was 6.3% higher in conventional than in organic. Titratable acidity is expressed as percentage of citric acid level (Figure 1). Pineapples grown in different location showed significant variations in their titratable.

Likewise the pH values varied significantly within the pineapple cultivars in conventional and organic being 1.6% higher in conventional.

The level of citric and malic acid in pineapple cultivars varied significantly between the two productions systems. The results showed that in organic production, citric acid was 15.8% higher than in conventional systems, while

Table 6. Total soluble solids, fructose, glucose and sucrose in mango and pineapple fruits.

Fruit	TSS (ºBrix)	Fructose (mg 100g $^{-1}$ FW)	Glucose (mg 100g $^{-1}$ FW)	Sucrose (mg 100g $^{-1}$ FW)	Origin	Production
Mango cultivars						
Dodo	14.2±1.1ab	2.26±0.36d	1.35±0.58de	5.00±2.29c	Tanzania	O
Bolibo	10.4±1.5c	2.37±0.57d	0.94±0.38e	7.29±2.0ab	Tanzania	O
Viringe	15.4±3.2a	2.29±0.49d	1.09±0.46e	6.52±0.13abc	Tanzania	O
Tommy Atkins	15.9±0.1a	3.87±0.36ab	2.09±0.19b	6.86±0.56abc	Burkina Faso	O
Kent	12.5±1.1bc	2.87±0.28cd	1.42±0.16cde	6.54±1.91abc	Costa Rica	C
Kent	15.9±0.1a	4.48±0.32a	2.67±0.17a	5.80±1.06abc	Ivory Coast	C
Kent	11.8±2.1c	3.32±0.22bc	1.88±0.18bc	7.92±0.59a	Mali	C
Kent	15.3±1.1a	3.48±0.87bc	1.85±0.17bcd	5.23±0.98bc	Peru	C
Pineapple cultivar						
Smooth cayenne	15.1±2.1ab	2.19±0.53b	2.12±0.78ab	7.14±0.54a	Tanzania	O
Smooth cayenne	13.0±0.7ab	2.49±0.45b	1.65±0.33bc	6.72±2.12ab	Uganda	O
Smooth cayenne	12.8±0.7b	1.68±0.30b	1.17±0.74c	3.40±1.21c	Costa Rica	C
Smooth cayenne	12.6±1.4b	3.76±1.21a	2.19±0.45ab	5.35±0.36b	Ghana	C
Smooth cayenne	16.0±0.1a	2.57±0.31b	2.82±0.35a	5.37±0.35ab	Honduras	C

malic acid was 30% higher in conventional than organic production system.

Lu et al. (2014) found that malic acid ranged from 30 to 161 mg/100 g FW and citric acids ranged from 114 to 578 mg/100 g FW in pineapple fruits. The lower malic acid levels in pineapple fruits found in the present study as compared with other literature might be due to the different methods of analysis or storage. Variation in time between harvesting and laboratory analysis could affect the quality.

Total soluble solids and sugar content

Total soluble solids content (TSS), sucrose, glucose and fructose are important quality attributes, as well as the determination of fruit maturity. They also influence the sweet flavour of the product. In mango, according to the variety and maturity, this variable ranges between 9.1 and 18.27%. The balance between organic acids and soluble sugars has an effect on the taste of fruits. In a study by Malundo et al. (2001), it was found during ripening that the level of acidity decreases and the total soluble sugar concentration increases due to conversion of starch into sugars. The sugar content of fruits has usually been assessed in terms of soluble solids content, or non-reducing and reducing sugars. Reducing sugars have been found to increase, or remain constant, during ripening. Glucose, fructose and sucrose have been reported to be in similar concentrations in ripe mangoes, and sucrose has been shown to be predominant throughout ripening.

In Table 6, total soluble solids values were found to vary significantly ($p \leq 0.05$) in mango cultivars under conventional and organic production system in different locations and this is in line with the studies of Leonardi et al. (2000), Goemez et al. (2001) and Moraru et al.(2004) who found that the total soluble solid content is cultivar dependent. In several studies by Andrews et al. (2001) and Reganold et al. (2001), it was found that soluble solids and total sugars content were higher in organic apples as compared with conventional. Total soluble solids (Gil et al., 2006) in mango ranged between 13.7 and 14.4%. These values corresponded with this study's findings only for '*dodo'* whereas the cultivars '*Tommy aktins' and* '*Kent*' had total soluble solid values above 15.0%. In the pineapple cultivar *'Smooth Cayenne'*, the values varied significantly in organic and conventional production system in different location. Gil et al. (2006) found that the total soluble solid in pineapple ranged between 11.1 and 13%; in this study, the pineapple cultivar *'Smooth Cayenne'* was shown to have total soluble solid value of 15.0 and 16.0 in some locations.

The levels of reducing and non-reducing sugars varied significantly ($p \leq 0.05$) among the mango cultivars in different locations and, between conventional and organic production systems. Fructose and glucose levels were 22 to 28% higher in conventional than in organic produced mango cultivars. It has been shown that the growing system and cultivar could influence the total and reducing sugar contents of tomato (Ünlü et al., 2011). Mango cultivars 'Tommy Aktins' have shown higher levels of glucose, fructose and sucrose. Environmental condition may influence the development of mango and as a result has effect on its quality (Saleh et al., 2009).

In pineapple, reduced and non-reducing sugars were significantly different among the fruits. Fructose and glucose levels were higher in conventional than organic produced pineapple fruits by 20%, while sucrose levels were almost organic and in conventional produced pineapple fruits. Anza et al. (2006) reported that since reduced sugars were not variety dependent, they were location dependent. In a study conducted by Reganold et al. (2010), they found that effects of interaction of factors such as farming practices, amount of soil nutrients, plant varieties, and time of harvest may affect the nutritional quality of products and could also complicate the comparison of food from organic and conventional systems. Although organic farming practices in comparison with conventional farming practiced were shown to improve soil quality (Figure 2).

Mineral content in fruits

Through the activity of soil microorganism and plants, human beings are able to obtain essential minerals nutrients (Lundegårdh, 2005). It is known that vitamins, minerals, water, and fibres are among the major constituents for a balanced diet (Barta et al., 2006). There are direct and indirect effects of minerals uptake on human health. The effects of minerals are directly observed on human nutrition as consequence of consuming fruit and vegetables.

In many foods vitamins, minerals, and fibre are added during processing to enhance the nutritional quality of a food, which has helped to decrease malnutrition (Larson-Duyff and Roberta, 2002).

A diet rich in potassium contributes to the lowering of blood pressure due to the blunting effects of salt (sodium), while higher blood pressure has been associated with inadequate intake of potassium (McCarronand Reusser, 2001).

Calcium is an essential element for the formation of bone and tooth structures, and, for this reason, calcium requirements are higher during adolescence. Cohen and Roe (2000) found that calcium is important to reduce the risk of osteoporosis, a condition in which decreased bone mass weakens the bone.

In plants, calcium is primarily associated with the pectic materials and it seems to have a major influence on the rheological properties of the cell wall, an important factor on the texture and storage life of fruit and vegetables. Calcium helps to maintain membrane integrity and cell structure, and in metabolic regulation, it acts as secondary messenger (Hepler, 2005; Boyer, 2009).

Magnesium is important for the synthesis of proteins, release of energy stored in the muscle and for the regulation of the body temperature. It plays a role in heart function and in the formation of bone, and the activation of over 100 enzymes (Lukaski , 2004).

Phosphorus is a primary bone-forming mineral. According to DiMaggio et al. (2000) inorganic phosphate is an essential compound for several physiological processes such as skeletal mineralization and multiple cellular functions, including glycolysis, gluconeogenesis, DNA synthesis, RNA synthesis, cellular protein phosphorylation, phospholipid synthesis and intracellular regulatory roles.

Manganese is important for bone development, and is involved in metabolism of amino acid, lipid, and carbohydrate. Manganese is also found in several enzymes such as mitochondrial superoxide dismutase, glutamine synthetase, arginase, and involved in activation of several hydrolases, transferases and carboxylases enzymes.

Arredondo and Núñez (2005) stated that iron (Fe) is needed in several essential proteins including the heme-containing proteins, electron transport chain and microsomal electron transport proteins, and iron-sulphur proteins. Iron is also involved in a number of enzymes, such as ribonucleotide reductase, prolylhydroxylase phenylalanine hydroxylase, tyrosine hydroxylase and aconitase.

Minerals could not be directly detected through visual inspection or consumption; hence they are referred to as credence attributes. Normally, in a quality control program, no incentive is given to measure minerals, unless there are specific nutritional claims. In judging quality, consumers base their perceptions on two kinds of quality attributes: purchase attributes which involve size, colour, firmness to the touch, aroma and absence of defects; and consumption attributes such as flavour and mouth feel (Shewfelt, 2000). Altieri and Nicholls (2012) found that mineral content could also affect most of these quality characteristics, and the acceptability of both fruit and vegetable is also influenced by several factors. In fruits, mineral levels could be influenced by several factors such as the variety of the produce item, time of harvest, ripeness, climate, natural soil nutrient status as well as the application of fertilizers, and possibly storage and marketing conditions.

Phosphorus content varied significantly among the mango cultivars and this may indicate the effect of cultivar on phosphorus content of the fruits (Table 7). The phosphorus content ranged between 5.9 and 8.9 mg $100g^{-1}$ FW, which is close to the findings indicated by Wojciech et al. (2009), where the mean phosphorus content in mango was 11 mg $100g^{-1}$ FW. Phosphorus content was found to be higher in organic than conventional produced mango, which may be influenced by location. In the comparison done by Worthington

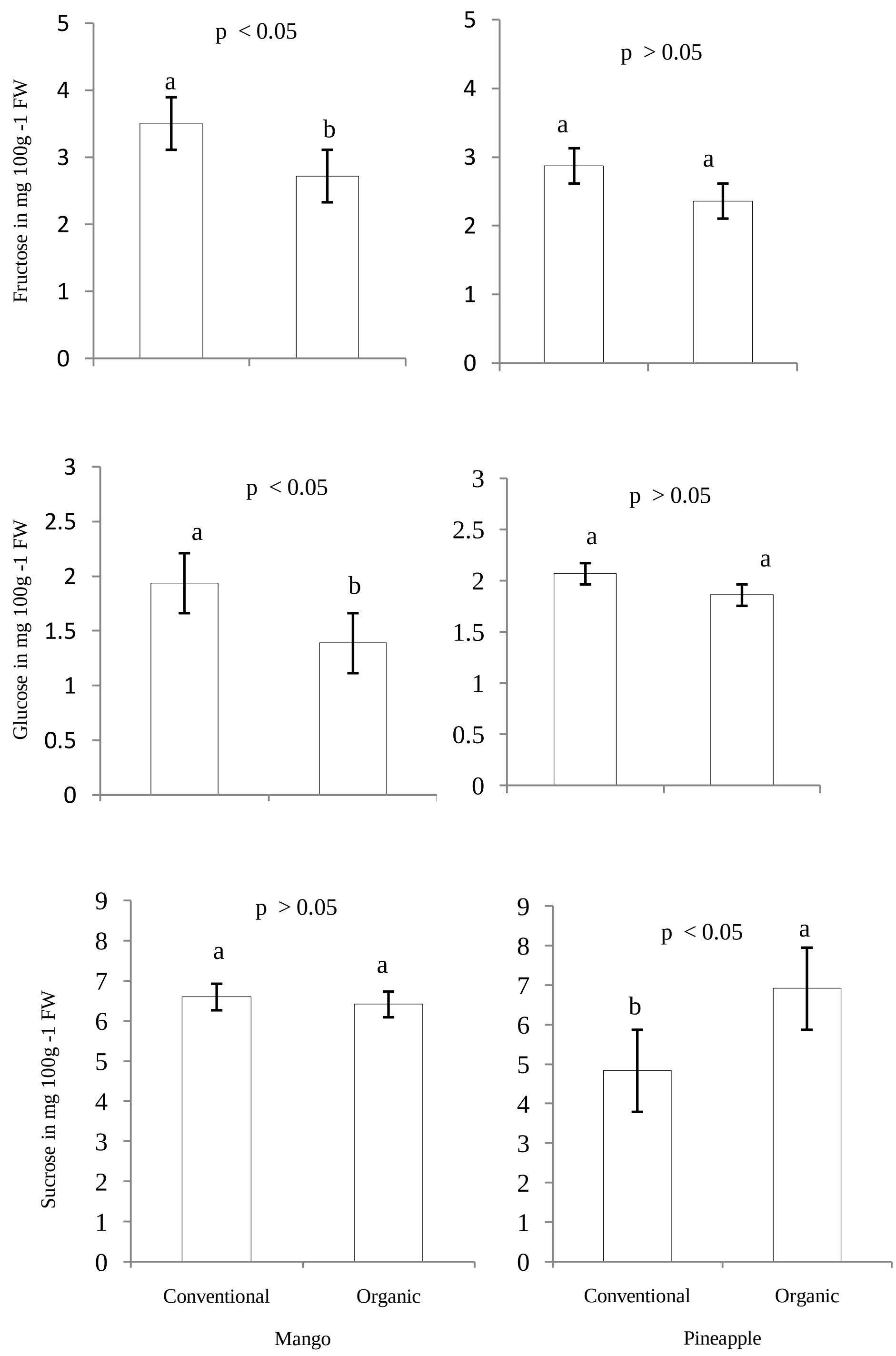

Figure 2. Sugar contents (mg $100g^{-1}$ FW) in conventional and organic in mango (n=12) and pineapple fruits (n=16). Values with different letters are significantly different ($p \leq 0.05$).

(2001), phosphorus content was found to be higher (1.8%) in organic than conventional crops.

Phosphorus content in pineapple did not vary significantly (Table 7) and ranged between 6.5 and 8.5 mg $100g^{-1}$ FW, and that is close to the value of 8.0 mg $100g^{-1}$ FW indicated by Wojciech et al. (2009). Phosphorus content was not significantly higher in organic than in conventionally produced mango and pineapple fruits.

Table 7. Macro and micro mineral content in mango and pineapple fruits.

Fruit	P	Ca	K	Mg	Fe	Mn	Origin	Production
	mg 100g^{-1} FW							
Mango cultivars								
Dodo	8.9±0.9a	13.7±1.8a	161.4±20.8a	16.0±3.2a	0.119±0.05c	0.024±0.011ab	Tanzania	O
Bolibo	8.4±2.8a	12.3±1.8a	162.9±18.1a	14.6±1.1abc	0.118±0.01c	0.021±0.013b	Tanzania	O
Viringe	7.9±1.1ab	11.9±1.3a	164.6±16.7a	16.6±1.8a	0.146±0.04abc	0.020±0.007b	Tanzania	O
Tommy Atkins	8.1±1.1a	11.8±0.8a	160.7±12.0a	13.2±0.3bc	0.175±0.01a	0.035±0.017ab	Burkina Faso	O
Kent	7.5±1.1ab	12.3±0.7a	145.6±8.8b	15.6±2.3ab	0.133±0.03bc	0.024±0.005ab	Costa Rica	C
Kent	7.3±0.5ab	13.9±3.7a	164.8±7.8a	16.2±1.3a	0.165±0.02ab	0.038±0.008a	Ivory Coast	C
Kent	5.9±1.8b	11.8±0.8a	145.5±8.8b	12.1±1.2c	0.116±0.02c	0.020±0.002b	Mali	C
Kent	7.9±1.7ab	11.0±1.1a	159.0±13.7ab	12.6±0.3c	0.148±0.03abc	0.019±0.002b	Peru	C
Pineapple cultivar								
Smooth cayenne	7.1±2.7a	11.3±1.8a	156.1±30.6a	12.4±1.9a	0.139±0.03a	1.368±0.29a	Tanzania	O
Smooth cayenne	8.3±0.7a	9.3±0.9ab	139.9±17.1b	11.4±0.7ab	0.143±0.04a	1.276±0.11ab	Uganda	O
Smooth cayenne	7.5±1.5a	7.5±1.3b	150.7±42.3a	10.8±4.0ab	0.141±0.04a	0.942±0.23b	Costa Rica	C
Smooth cayenne	8.5±3.8a	11.0±1.7a	150.7±19.2a	9.6±7.3b	0.127±0.08a	0.976±0.17b	Ghana	C
Smooth cayenne	6.5±1.3a	7.1±0.4b	156.1±15.9a	11.5±2.1ab	0.145±0.02a	1.101±0.26ab	Honduras	C

Values within columns of the same fruits with different letters are significantly different ($p \leq 0.05$)
P = Phosphor, Ca = Calcium, K= Potassium, Mg = Magnesium, Fe = Iron and Mn = Manganese.

Calcium content in mango cultivars ranged between 11.3 and 13.9 mg 100g-1 FW as compared with 8 mg 100g-1 FW found in the study conducted by Cunnighamet al. (2001). There was a slight variation of calcium between organically and conventional cultivated mango cultivars (Figure 3), which shows that the cultivation methods could influence the calcium content of the mango fruits. In pineapple samples, Calcium content ranged between 7.1 and 11.3 mg 100g-1 FW. In a study carried out by Cunnigham et al. (2001), 9 mg 100g-1 FW in pineapple fruits was observed. Calcium content was 20% higher in organic than in conventionally produced pineapple fruits. The calcium content was found to be higher in organic than conventional crops (Magkos et al., 2009). Magkos et al. (2009) noted that climatic factor may influence the variation of nutrient levels in products even when other variables are controlled, which may later result in difficulties in comparing the products. Organic pineapple has shown to posses significant higher calcium content than conventional ($p < 0.05$). Gastol and Domagala-Swiatkiewicz (2012) also found the contents of calcium to be higher in organic than in conventional fruits. The cultivation practices could influence the chemical composition of fruits; the variation in their contents can even occur within a similar variety (Sturm et al., 2003; Lee et al., 2003).

Potassium content ranged between 145.5 and 164.6 mg 100g^{-1}FW in mango cultivars, Cunnigham et al. (2001) found 160 mg 100g^{-1}FW in mango fruits, which is close the range found in this study. Potassium contents was10% higher in organic than conventional produced mango

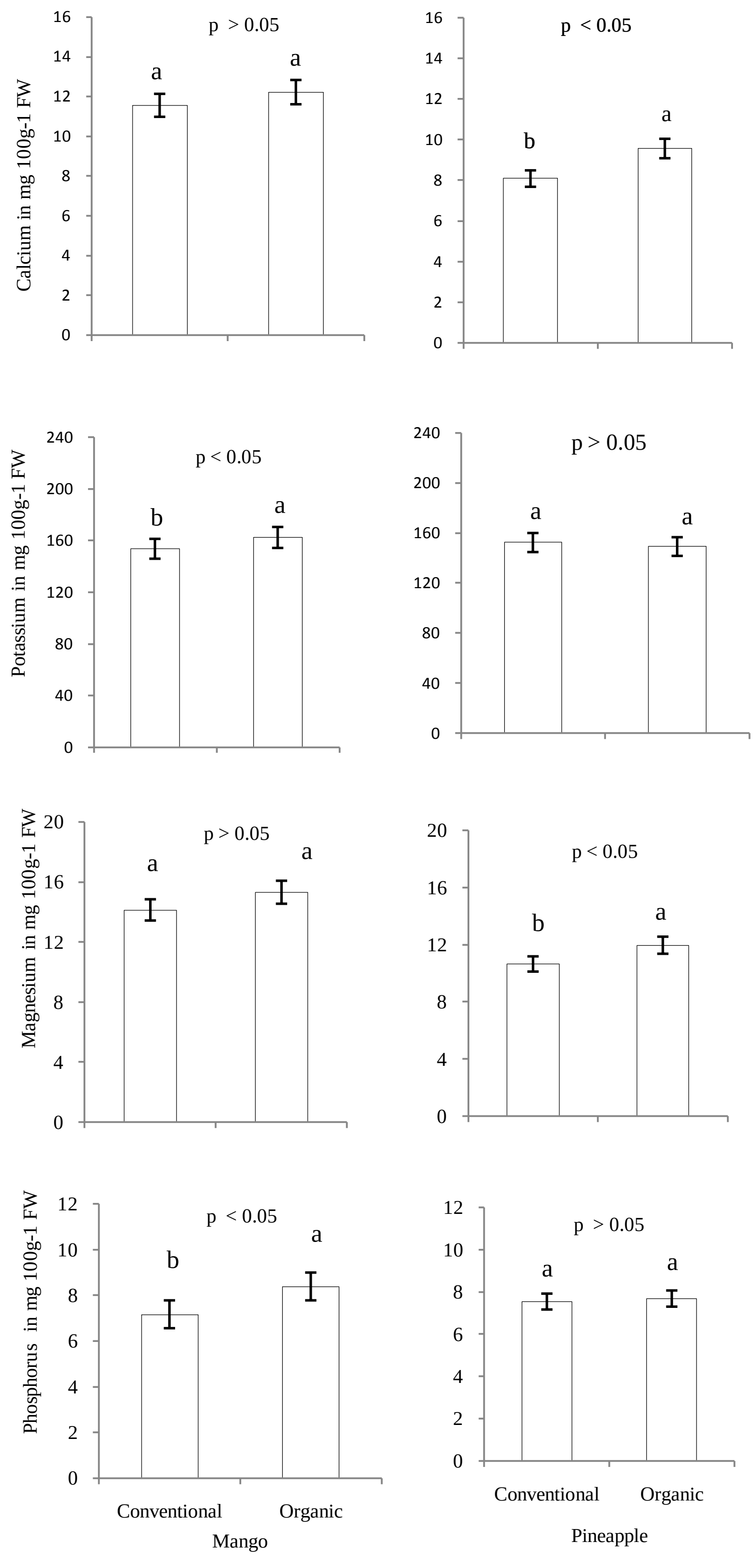

Figure 3. Macro mineral contents (mg $100g^{-1}$ FW) in conventional and organic mango (n=12) and pineapples fruits (n=16). Values with different letters are significantly different ($p \leq 0.05$).

cultivars (Figure 3). It has been noted that organic plants have relatively larger root-balls to absorb a wider variety of nutrients than chemically fertilized plants, due to the fact that the concentration of potassium affects water uptake from the soil and water retention in the plant tissues. Another fact is that macronutrients are less readily available in organic system than in conventional, so root systems of plants in organic system must grow larger to take up nutrients (Prasad, 2008). Furthermore, roots of plants grown in organic agricultural system have wider range to access sufficient nitrogen, phosphorous and potassium. As a result, in farms that are managed organically, plants come into contact with more micronutrients, such as iron and manganese, than the smaller root-balls of plants in conventional agricultural system (Prasad, 2008). In conventional farm, the availability of fertilizer nutrients in the soil is high along with lots of water, as a result, roots are likely to proliferate less than under organic conditions in order to absorb adequate nutrients (Worthington, 2001). Potassium contents do not vary significantly between conventional and organically produced pineapple fruits. It has been noted in some plants that potassium fertilizers could reduce the content of magnesium and indirectly content of phosphorus, and when soils are provided with potassium, the absorption of magnesium by the plant is reduced. This is due to the fact that absorption of phosphorus depends on magnesium, which makes phosphorus to be less available. In conventional systems, potassium fertilizer dissolves readily in soil water, providing crops with an adequate supply of potassium, while organic systems soils tend to hold more moderate and available quantities of both potassium and magnesium around the root zone (Worthington, 2001).

Mango has been shown to posses magnesium content of between 12.1 and 16.6 mg 100 g^{-1}FW as compared with 10 mg 100g-1FW found by Cunnigham et al. (2001). Magnesium content was on average, that is, 8.3% higher in organic than conventionally produced mango cultivars. Worthington (2001) found that crops grown in organically managed farms have 29.3% higher content of magnesium than crops grown in conventional agricultural system, and this could be attributed to the fact that in organic farming, soil organic matter is involved in nutrient cycling by supplying and holding nutrients, also more efficient in holding water (Worthington, 2001). In mango fruits magnesium content varied significantly among mango cultivars, where by cultivars *'Viringe'* and *'Dodo'* have been shown to have higher magnesium content of 16.6 and 16.0 mg 100g^{-1} fresh weight, respectively, and in one location cultivar *'Kent'* has shown to have magnesium content of 16.2 mg 100g^{-1} fresh weight. This may show that the levels of magnesium content in mango fruits could be influenced by type of cultivars and location. Pineapple was found to have magnesium content of between 9.6 and 12.4 mg 100g^{-1}FW as compard with 13 mg 100g^{-1}FW found by Cunnigham et al. (2001). Magnesium content was with average 12.3% higher in organic than in conventionally grown pineapple fruits. In organic and conventional agricultural systems, potassium is presented differently to plants. In conventional agricultural systems, potassium dissolves readily in soil when added with potassium fertilizers, resulting in high amount of potassium in crops, while for soil managed in the organic agricultural system, the root zone of the crops tends to hold moderate amounts of both potassium and magnesium (Worthington, 2001).

The iron contents among mango cultivars ranged between 0.116 and 0.175 mg 100 g^{-1} FW, which was slightly below 0.2 mg 100 g^{-1} FW found by Cunnigham et al. (2001). The iron content varied significantly among the mango cultivars, although variation between conventional and organically produced mango fruits was not significant (Figure 4). There was significant variation in terms of iron content between organic and conventionally cultivated mango cultivars. Iron content was 3.1% higher in conventional than in organic mango, which was not significant (Figure 4). Gastol and Domagala-Swiatkiewicz (2012) found in their study that species and farming method has effect on mineral content of fruit juices. A comparative studies conducted by Worthington (2001) and Fliessbach and Mäder (2001) showed that higher levels of mineral element, such as iron, magnesium and phosphorus, in organic raw materials were influenced by higher levels of microorganism in the soil. In pineapple, iron content ranged between 0.127 and 0.145 mg 100g-1 FW, which is slightly below 0.2 mg 100g-1 FW (Cunnigham et al., 2001). Organic pineapple when compared with conventional pineapple fruits was shown to have 2% higher content of iron (Figure 4). Gastol and Domagala-Swiatkiewicz (2012) found that the cultivation system has no influence on iron juice content. Organically managed soils has been found to have more micro-organisms (Worthington, 2001).These micro-organisms produce several compounds, such as citrate and lactate, that combine with soil minerals and make these minerals more available to plant roots, especially iron, which is found in many soils in adequate amount but in an unavailable form. Method of farming has been shown to have significantly higher mineral content in organically grown than non-organically grown fruit and vegetables (Holden, 2001).

Manganese content among the mango cultivars ranged between 0.019 and 0.038 mg 100g^{-1} FW, which correspond with 0.027 mg 100g^{-1} FW indicated by Wojciech et al. (2009). Manganese content variation was not significant in both conventional and organically cultivated mango cultivars, similar observations was noted by (Lairon, 2010) who found that the production systems could not significantly influence variation of the mineral

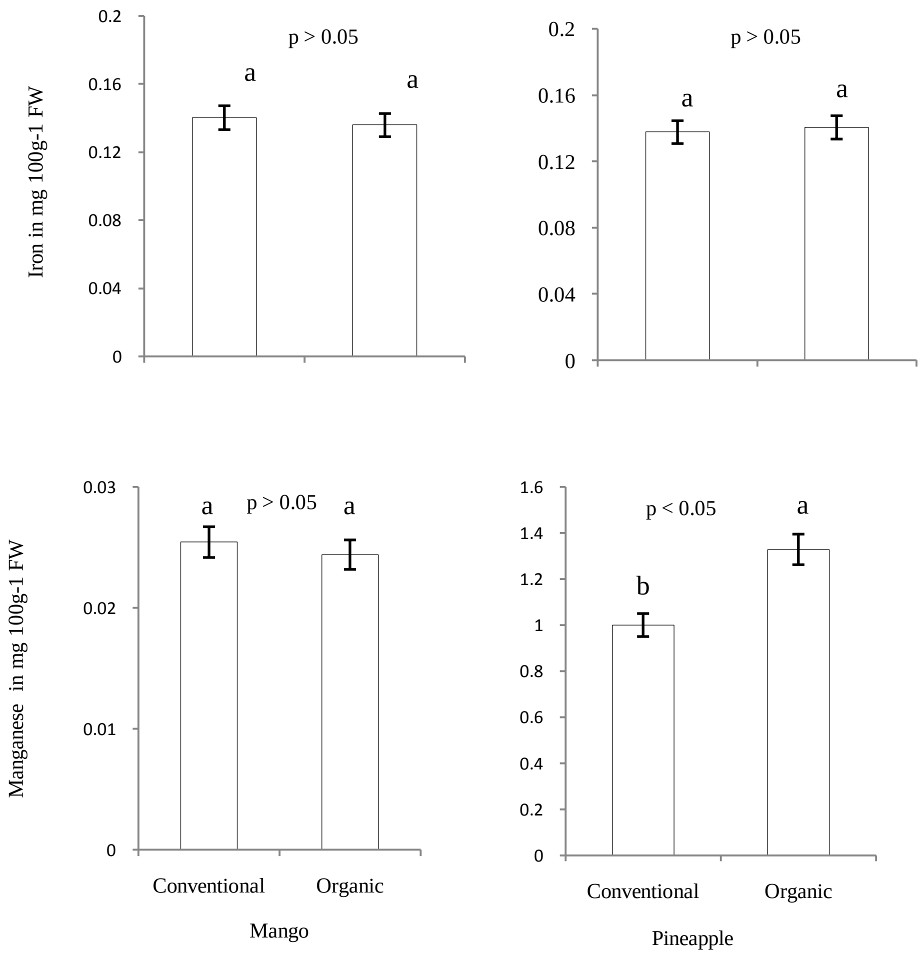

Figure 4. Micro mineral contents (mg $100g^{-1}$ FW) in conventional and organic mango (n=12) and pineapples fruits (n=16). Values with different letters are significantly different ($p \leq 0.05$).

composition of apple fruits.

It has also been reported that mineral contents in strawberry was not affected consistently by organic cultivation (Hakala et al., 2003). Manganese content varied significantly ($p \leq 0.05$) among pineapple fruits from different cultivation and location. Manganese content was 32.8% higher in organically than conventionally produced pineapple fruits; this shows the effect of method of production and location on manganese content of pineapple fruits. In organic agricultural practice, soil has high organic substances, which serves as chelates for micronutrient metals. These chelates are soluble organic compounds that bind metals and increase their solubility and availability to plants (McCauley et al., 2009). The results showed that the pineapple fruits with manganese content ranged between 0.942 and 1.368 mg $100g^{-1}$ FW, which is close to 0.927 mg $100g^{-1}$ FW reported by Wojciech et al. (2009).

In fresh fruits and vegetables, the composition of minerals fluctuates due to pre-harvest factors, such as soil fertility, which includes pH and nutrients availability to plant, soil moisture content, growth temperature and agricultural practices determined by the amount and timing of fertilization and irrigation, the application of plant growth regulators, pruning and thinning of tree fruit species (Wojciech et al. 2009). A study by Crisosto and Mitchell (2002), it was shown that, in most cases, these practices have been developed to increase yields and improve quality of products suitable for human health and the practices also have influence on post-harvest life or flavour quality of horticultural crops. Normally, fertilizers are applied with the aim of raising nutrient levels for the successful growth of the crop, and to maintain the fertility of the soil.

Conclusion

This study shows that the variations in nutritional characteristics of fruits could be influenced by agricultural practice, geographical location and genetic variation between cultivars. Mango and pineapple fruits from different locations showed significant variations in their glucose, fructose, sucrose and total soluble solids contents. Organic acid, titratable acidity and pH levels in the fruits varied significantly among the mango and pineapple fruits from different locations. There were significant variations in mineral contents among pineapple and mango fruits produced in different locations. These results indicate the influence of location on nutritional status of fruits. Sugar, minerals and organic acids contents varied among different cultivars of mango fruits, indicating that there is correlation between type of fruit cultivars and quality attributes of the fruits. The type of cultivation may influence variability in the quality of fruits components in terms of sugar, mineral and organic acid contents. It can be concluded from the study that levels of nutritional variables of mango and pineapple of the same cultivar and same climatic condition could significantly be affected by the type of agriculture practices influencing the rates of availability of plant nutrients.

Organic farming promotes production without the use of synthetic chemicals or fertilizers while enhancing soil composition and promoting biodiversity. This type of production relies on ecosystem services to maintain the integrity of the landscape while still producing sufficient yields. Conventional farming uses synthetic chemicals and fertilizers to maximize the yield of a particular crop or set of crops, whereby systems requires a significant amount of chemical and energy input and weakens the ecology of a landscape. It is important to highlight the fact that the fruits studied differed in soil composition, geography, and rotation systems, which has contributed to variation of their quality attributes.

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