Antioxidant Capacity in Organically and Conventionally Grown Mango (Magnifera indica L.) and Pineapple (Ananas cosmos)

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Research Paper

Antioxioant Capacity in Organically and Conventionally Grown Mango (*Magnifera indica* L.) and Pineapple (*Ananas cosmos*)

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Abbreviations: AA: Ascorbic acid, GAE: Gallic acid equivalents, FW: Fresh

ABSTRACT

Organically grown mango (*Mangifera indiga* L. *cv. Dodo, Bolibo, Viringe*) and pineapple (*Ananas comosus* L. *cv. Sooth cayenne*) from Tanzania were compared to organically (*cv Tommy Atkins*) and conventionally (*cv Kent*) grown mango and pineapple (*cv Smooth cayenne*) cultivars from seven other countries purchased in markets in Germany. The influence of cultivar, agricultural practice and geographical location on total antioxidant capacity, total phenolics, carotenoids and ascorbic acid levels were determined. Cultivars, agricultural practices and geographical location showed influence on some of the quality attributes of the fruit. Ascorbic acid was significantly higher conventionally than in organically produced mango and pineapple at different locations. Antioxidant capacity was higher by 22% in conventionally than organically grown mango. The total carotenoids content was 17% higher in organic than in conventional mango, and 21% higher in conventional than in organically produced pineapple.

Key words: Total antioxidant capacity, total phenolic compounds, total carotenoids and ascorbic acid, mango, pineapple.

INTRODUCTION

Organic food sales increased by about 20% per year since 1990, and were estimated at $10.4 billion in 2003 on the U.S. market alone (Oberholtz et al., 2005). Consumer studies showed multiple reasons for organic preferences, including environmental and socio-economic concerns, enhanced taste, and the assumption that organic foods are healthier (Shepherd et al 2005).

Quality values distinguish between species depending on genetically-determined differences. The quality target for crop production is to reach the best possible composition of compounds or groups of compounds that are important in nutrition and consumer health. These compounds are created in primary and secondary synthesis pathways in plants (Lundegårdh, 2005).

Agronomic practices play a role in determining the quality of food with respect to health and safety attributes; differing soil management between organic or conventional production are key determinants of differences in quality and safety. Very few studies compared nutrient and bioactive compounds in organic and conventionally produced foods (Lombardi-Boccia et al., 2004).

High consumption of fruits and vegetables was observed to be associated with a lower incidence of degenerative diseases in consumers (Ribeiro et al,. 2007). Such protective effects are thought to be partially associated with the presence of various antioxidant compounds (Kauer and Kapoor, 2001). Mango (*Mangifera indica* L.) and pineapple (*Ananas cosmos)* are among the most important commercial crops in Tanzania. These fruits are considered as a good source of dietary antioxidants, such as amino acids, carotenoids and phenolic compounds (Sánchez-Moreno et al., 2006).

Fruit and vegetables contain various bioactive compounds such as vitamins A, C and E, with a high

antioxidant capacity (Hassimoto et al., 2005; Sanchez – Moreno et al., 2006) and phenolic compounds, which are good contributors to the total antioxidant capacity of the foods Cano et al., 2003; Chaovanalikit and Wrolstad, 2004), although, their nutritional relevance is uncertain because they may be poorly absorbed and rapidly metabolized and thus, have limited antioxidant ability *in vivo* (Gardner et al., 2000).

The study of natural antioxidants has become popular due to increased demand in the market for so-called functional or health foods (Andlauerand Fürst, 2002).

Ascorbic acid (AA) is an essential human diet component and acts as an antioxidant and therefore offers some protection against oxidative stress-related diseases (Zulueta et al., 2007). The action of phenolic compounds in foods has received some attention because of their biological activity in cancer and heart diseases prevention (Kris-Etherton et al 2002).These compounds are preferably oxidized in biological medium and function as antioxidant nutrient economizer, protecting organisms against the oxidative stress (Ribeiro et al., 2008).

Among the carotenoid pigments widely distributed in plant tissues, β-carotene provides the highest vitamin A activity. Vitamin A and its metabolites are essential for vision, reproduction, and immune function, besides performing other important physiological functions, including the deactivation of reactive oxygen species (Ball, 2004).

Fruit contains various carotenoids, which are a group of red, orange, and yellow pigments. Several of the carotenoids are vitamin A precursors. Carotenoids also function as quenchers of singlet oxygen, antioxidants, in gene activation, and inflammation and immune processes as a modulator of lipoxygenases (Ajila et al., 2007).

There is a significant correlation between the high intake of fruit and vegetables and the low incidence of some kinds of cancer and cardiovascular disease (Dragsted et al., 2006). This may be due to the protective effect of fruit and vegetables caused by the presence of a wide range of different antioxidants found in dietary plants (Halvorsenet al., 2002). While antioxidants are produced by the human body as well, the antibody defence mechanism could be further strengthened with a diet rich in antioxidant compounds. Several antioxidants with varied chemical characteristics are found to act together in a synergistic way (Blomhoff et al., 2006). A wide range of antioxidants was found in dietary plants as potential sources especially fruits, vegetables and nuts as well (Halvorsen et al., 2002).

The aim of this study was to compare the influence of agricultural practice, cultivar and geographical locationon antioxidant capacity, phenolic content, carotenoids content and ascorbic acid levels of mango and pineapple fruit

MATERIALS AND METHODS

Sampling

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 flight to Germany. Fruits obtained from shops in Göttingen, Germany were organic mango *cv. Tommy Atkins* from Burkina Faso, conventional mango *cv. Kent* from 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 fruits used were obtained between January and March, 2006, 2007 and 2008 and analyzed. All fruits were at acceptable ripened stage and their eating quality was considered. They were grouped into five fruits each for mango and pineapple. Fruits were cooled to 5 to 7° C before cutting.

Ferric reducing antioxidant power (FRAP method)

The antioxidant capacity of fruits was estimated using the FRAP assay (Connor et al., 2002), using a spectrophotometer (Hewlett Packard 8453, Germany).

The antioxidant capacity of a fruit was determined by its ability to reduce ferric iron to ferrous in a solution of 2, 4, 6-tripyridyl-2-triazine (TPTZ) prepared in sodium acetate at pH 3.6. The reduction of iron in the TPTZ-ferric chloride solution (FRAP reagent) results in the formation of a blue product (ferrous tripyridyltriazine complex). FRAP assay was done by putting 100 µl of the sample into the cuvette and 1 ml FRAP reagent added and mixed thoroughly, then, incubated for 4 min at 37°C in a water bath; the absorbance was measured at 593 nm against zero blank (1 ml FRAP reagent and 100 µl methanol). The antioxidant standard curve (50 to 1000 mM ferrous ion) was developed using ferrous ammonium sulphate. The results are expressed as millimoles of ferrous equivalents per gram of fresh weight.

Total phenolic content

The total phenolic substances were determined photometrically using the Folin-Ciocalteu method (Singleton and Rossi, 1965). The calibration curve was prepared with different concentrations of gallic acid (the same amount of a 0.5 mol L^{-1} sodium hydroxide solution and Folin-Ciocalteu reagent). For the measurement, 500 µl of sample, 1 ml of sodium hydroxide solution, 100 µlFolin-Ciocalteus reagent and 2.4 ml distilled water were used, mixed and set into the water bath (T=37°C) and incubated for 15 min. The measurements were done on a spectrophotometer (Hewlett Packard 8453, Germany) at 735.8nm. The total phenol contents of fruit juices were determined in triplicate and expressed in gallic acid equivalents (GAE).

Total carotenoids content

According to (Wellburn, 1994), 0.2 g of freeze dried sample was put in 5 ml of methanol and mixed on Vortex for one minute and then, shaken for 10 min and finally centrifuged at 3500 rev/min for 15 min. The extraction with methanol was repeated thrice and finally the supernatants were measured at 470, 563 and 666 nm absorbance with spectrophotometer (Hewlett Packard 8453, Germany). The following equations were used for total carotenoid determination:

Chlorophyll a (Chl a) = $(12.19 \times A_{665}) - (3.45 \times A_{649})$ µg/ml
Chlorophyll b (Chl b) = $(21.19 \times A_{649}) - (5.32 \times A_{665})$ µg/ml
Total Carotenoid = $((1000 \times A_{480}) - (2.14 \times \text{Chl a}) - (70.16 \times \text{Chl b}) / 220$ µg/ml

Ascorbic acid

AA was determined by titration method (Albrecht, 1993). Five grams of the samples were immersed in 20 ml metaphosphoric acid (5%) in 50 ml tube and homogenized by ultra turrax for 2 min and thereafter the addition of distilled water up to the volume. Then, the solution was filtered using filter paper. The filtrate (10 ml) was titrated with 0.21% 2, 6 dichlorophenol-indiphenol (DIP) solution drop by drop until light red orange colour was achieved. The amount of DIP solution used was recorded for the calculation of the AA content in the sample tested using the formula:

Ascorbic acid (mg $100g^{-1}$ juice) = ml DIP × 0.1 × (50/10) × (100/weight sample)

Statistical analysis

Collected data were entered into a spreadsheet and imported into SigmaStat program version 2, where various statistical tests were performed using ANOVA. Least significant different (LSD) test and a multiple comparison test was performed in an attempt to discern if significant differences existed between any of the sample means.

RESULTS AND DISCUSSION

Antioxidant capacity in fruits

Fruits and vegetables are rich sources of several micronutrients and phytochemicals with antioxidant properties said to be protective against chronic degenerative health disorders (Cox et al., 2000; Szeto et al., 2002). These compounds with antioxidant properties include vitamin C and E, carotenoids and phenolic compounds, especially flavonoids. Fruits and vegetables have antioxidants which could act against oxidative stress, protect cells against oxidative damage and also prevent chronic diseases like cancer, cardiovascular disease and diabetes (Podsedek, 2005). Normally, nutrient antioxidants function as synergists, due to this they are more effective together rather than as single antioxidant in lowering the levels of oxygen species (Eberhardt et al., 2000; Ohr, 2004; Podsedek, 2005; Trombino et al., 2004). Fruits and vegetables contain other important nutrients which are essential to human health because the human body is not able to produce them. These substances include water, protein, lipid, minerals and /or vitamins.

In Table 1, the total antioxidant capacities showed variations within the mango cultivars, which were significant at $p \leq 0.05$. Mango cultivar *'Kent'* showed the highest and '*Tommy Atkins*' the lowest value in their total antioxidant capacity, which could be influenced by cultivar differences. The mango cultivar *'Kent'* produced under conventional production system in different locations differed significantly in their total antioxidant capacities. This suggests that the geographical location may influence the total antioxidant of the mango cultivar due to different soil types and climate conditions. The total antioxidant capacities of mango cultivars under conventional production systems were 22% higher as compared with mango cultivars under organic production system (Figure 1), showing that the production systems could affect the total antioxidant capacity of mango fruits.

The pineapple cultivar `*Smooth Cayenne*' from different countries showed significant differences in their total antioxidant capacities ($p \leq 0.05$), which implies that there is effect of location on total antioxidant capacities. The conventional pineapple fruits showed 5.7% higher total antioxidant capacity than organically produced pineapple, indicating the influence of cultivation methods on the levels of the total antioxidant capacity in pineapple fruits. Young et al. (2005) and Chassy et al. (2006) found that different crops may respond differently to agronomic factors such as nutrient availability. There is evidence suggesting higher levels of antioxidant and vitamins in organically than those conventionally produced (Weibel et al., 2000; Asami et al., 2003; Chassy et al., 2006; (However, there is also a study that shows either results that are opposite, or results that show no difference (Winter and Davis, 2007). Barrett et al. (2007) concluded that it is not possible to ensure that, from a nutritional point of view, organically grown products are superior to those obtained by conventional agricultural techniques.

Total carotenoids content of fruits

In a study done by Rao and Rao (2007), it was found that

Table 1. Antioxidant capacity in mango and pineapple fruits.

Fruit / Mango cultivars	Antioxidant capacity (mMol Fe^{2+} 100 g^{-1}FW)	Origin	Production
Dodo	$0.48±0.18^{abc}$	Tanzania	Organic
Bolibo	$0.45±0.17^{bc}$	Tanzania	Organic
Viringe	$0.42±0.08^{c}$	Tanzania	Organic
Tommy Atkins	$0.36±0.06^{c}$	Burkina Faso	Organic
Kent	$0.49±0.1^{abc}$	Costa Rica	Conventional
Kent	$0.63±0.17^{a}$	Ivory Coast	Conventional
Kent	$0.61±0.13^{ab}$	Mali	Conventional
Kent	$0.49±0.04^{abc}$	Peru	Conventional
Pineapple cultivar			
Smooth cayenne	$0.34±0.04^{b}$	Tanzania	Organic
Smooth cayenne	$0.57±0.15^{a}$	Uganda	Organic
Smooth cayenne	$0.56±0.29^{a}$	Costa Rica	Conventional
Smooth cayenne	$0.44±0.2^{ab}$	Ghana	Conventional
Smooth cayenne	$0.45±0.14^{ab}$	Honduras	Conventional

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

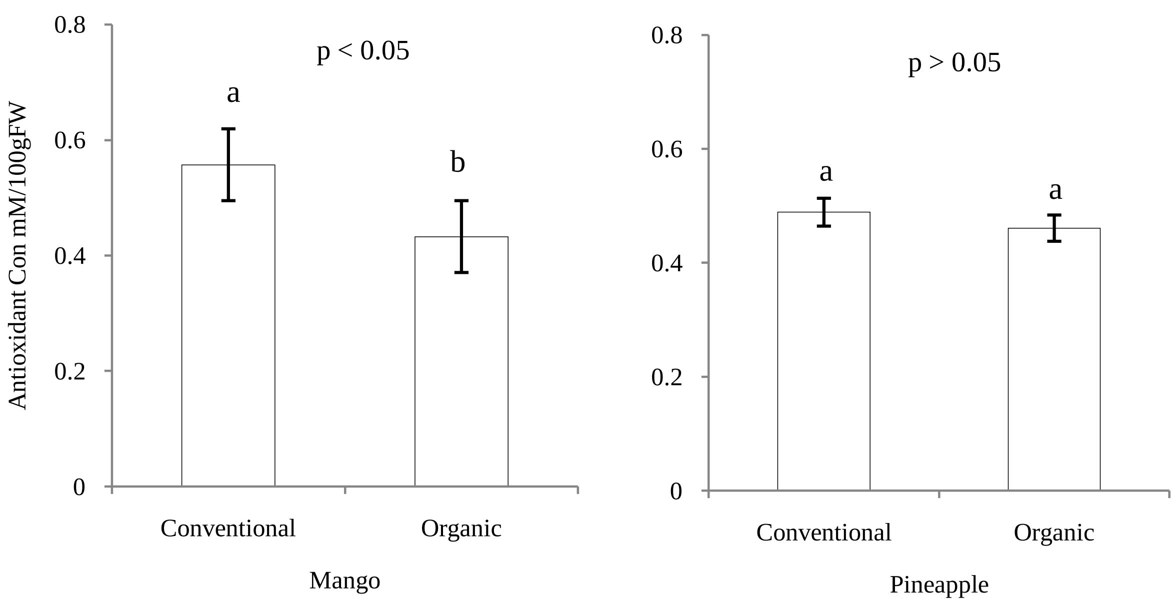

Figure 1. Total antioxidant capacity in conventional and organic in mango (n=12) and pineapple fruits (n=16). Values with different letters are significantly different ($p \leq 0.05$).

fruits and vegetables are major source of carotenoids. These compounds contain conjugated double bonds which cause them to act as antioxidants (Sandmann, 2001). Recently, further studies were done on carotenoids effects on antioxidant capacity and the ability to prevent diseases. Carotenoids are used as food additives (Breithaupt, 2004) and the yellow-reddish colour of many foods are due to the presence of carotenoids, which are natural pigments found abundantly in fruits and vegetables (Dutta et al., 2005; Mortensen, 2006). According to Rodriguez-Amaya (2001) mango fruits could provide provitamin A carotenoids, especially β-carotene.

Mango cultivars showed significant differences at ($p \leq 0.05$) in their total content of carotenoids (Table 2). Mango cultivar *'Viringe'* showed highest content in the total carotenoids content of 2.87 mg 100g^{-1} FW. The mango cultivars 'Kent' grown at different locations varied significantly in their total carotenoid contents, indicating

Table 2. Total carotenoids content in mango and pineapple fruit.

Fruit / Mango cultivars	Total carotenoids (mg 100 g^{-1} FW)	Origin	Production
Dodo	2.13±0.82^{ab}	Tanzania	Organic
Bolibo	1.87±0.68^{ab}	Tanzania	Organic
Viringe	2.87±0.97^{a}	Tanzania	Organic
Tommy Atkins	1.52±0.89^{b}	Burkina Faso	Organic
Kent	1.96±0.75^{ab}	Costa Rica	Conventional
Kent	1.37±0.55^{b}	Ivory Coast	Conventional
Kent	2.21±1.06^{ab}	Mali	Conventional
Kent	1.76±0.95^{ab}	Peru	Conventional
Pineapple cultivar			
Smooth cayenne	1.17±0.46^{a}	Tanzania	Organic
Smooth cayenne	1.98±0.32^{a}	Uganda	Organic
Smooth cayenne	2.0±1.0^{a}	Costa Rica	Conventional
Smooth cayenne	1.69±1.0^{a}	Ghana	Conventional
Smooth cayenne	1.58±1.0^{a}	Honduras	Conventional

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

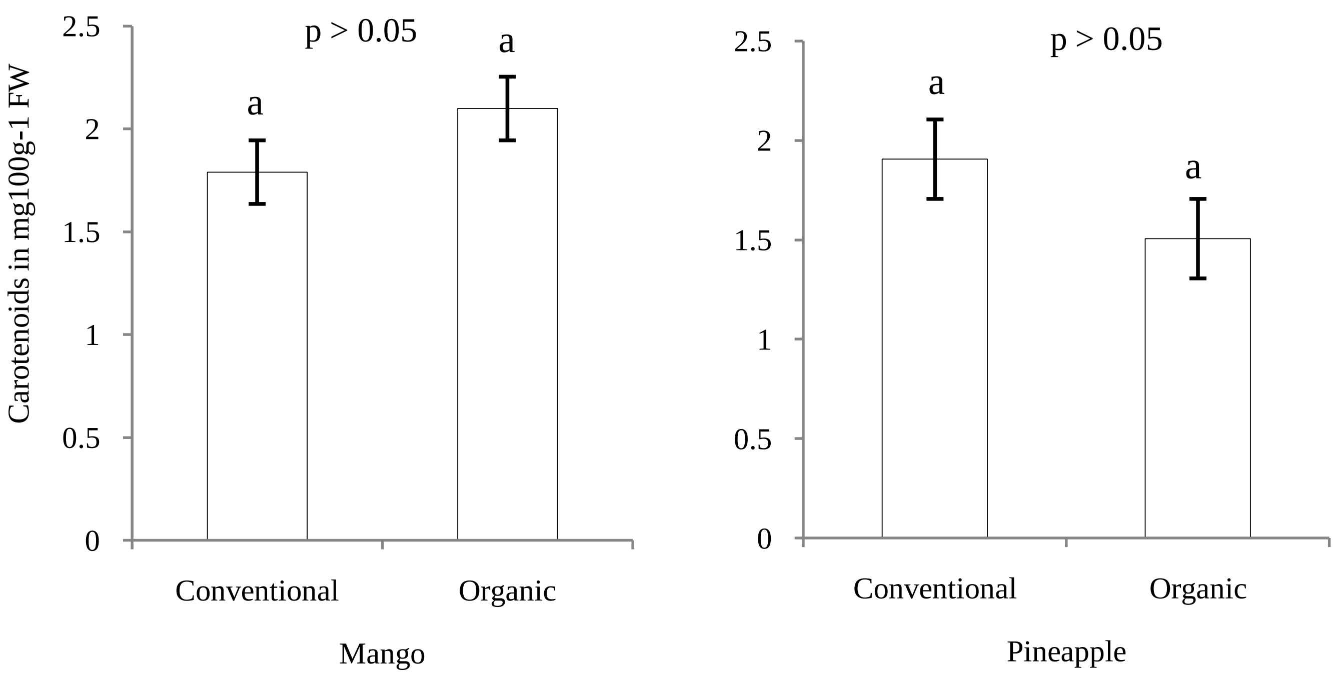

Figure 2. Total carotenoid content in mango (n=12) and pineapple fruits (n=16). Values with same letters are not significantly different ($p \geq 0.05$).

that location may influence the total carotenoid contents of the fruits. The total carotenoid content was 17.3% higher in mango cultivars from organic than in conventional production systems (Figure 2). This may imply that the agricultural methods could have effect on total carotenoids content of the fruits. Winter and Davis (2006) stated that fruits and vegetables crops grown in organic farms are not applied chemical pesticides or synthetic fertilizers and instead they synthesize beneficial secondary plant metabolites such as polyphenolic antioxidants as well as, naturally occurring toxins. Climatic effects are seen in fruits of the same cultivars cultivated in regions of different climates, elevated temperature and greater exposure to sunlight, thereby, increasing carotenogenesis. The total

Table 3. Total phenolic content in mango and pineapple fruits.

Fruit	Total phenolic content (mg 100 ml^{-1} juice)	Origin	Production
Mango cultivars			
Dodo	2.71±0.44^{ab}	Tanzania	Organic
Bolibo	3.08±0.17^{a}	Tanzania	Organic
Viringe	2.77±0.40^{ab}	Tanzania	Organic
Tommy Atkins	2.47±0.11^{b}	Burkina Faso	Organic
Kent	2.69±0.64^{ab}	Costa Rica	Conventional
Kent	2.99±0.20^{a}	Ivory Coast	Conventional
Kent	2.72±0.33^{ab}	Mali	Conventional
Kent	3.07±0.05^{a}	Peru	Conventional
Pineapple cultivar			
Smooth cayenne	2.95±0.11^{a}	Tanzania	Organic
Smooth cayenne	3.05±0.43^{a}	Uganda	Organic
Smooth cayenne	2.99±0.21^{a}	Costa Rica	Conventional
Smooth cayenne	2.91±0.38^{a}	Ghana	Conventional
Smooth cayenne	2.93±0.36^{a}	Honduras	Conventional

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

carotenoids contents were found to range from 1.17 to 2.06 mg 100g^{-1} FW in pineapple fruits cultivar *'Smooth Cayenne'*. Joomwong (2006) found the pineapple cultivar *'Smooth* Cayenne' has average carotenoid content between 1 to 1.5 mg 100g^{-1} FW. In our study, pineapple cultivar '*Smooth Cayenne'* showed slight differences which were not significant ($p \geq 0.05$) in their total carotenoid content. Stracke et al. (2009) found in their study that carotenoids content did not vary between organic and conventional grown fruits. Although, the total carotenoid was not significant ($p \geq 0.05$) among pineapple cultivars, the total carotenoid content was on average 21% higher in pineapple fruits under conventional than organic production system (Figure 2), which suggests that cultivation system may have influence on carotenoid content of the pineapple fruits.

Due to rapidly available nitrogen in the conventional farming system plant diverts sugars from photosynthesis to produce more proteins and a spike in vegetative growth. As a result plant produces more leaves, and thus more chloroplasts, which brings out higher carotenoids production. Rodriguez- Amaya (2001) stated that carotenoid content in fruits could be influenced by some differences such as the stage of maturity, cultivar, and post-harvest handling procedures. There are qualitative differences due to factors such as cultivar or variety, climate or geographic site of production and farming practices, which could influence carotenoids contents in food (Dutta et al., 2005).

Total phenolics content of fruits

Phenolic compounds belong to secondary metabolites which which are by-products of physiological processes occurring in plants. Studies done by Podsedek (2005) and Balasundram et al. (2005) found these derivatives of pentose phosphate, shikimate and phenylpropanoid pathways showed a strong antioxidant effect against free radicals as well as, to other reactive oxygen species. Natural phenolic antioxidants showed health promoting benefits and as a result, fruits and vegetables became more important in human nutrition. The bio-functional health-promoting properties of phenolic compounds led scientists to investigate their availability in fruits and vegetable, as important sources of such compound (Moure et al., 2001).

Health promoting properties of fruits were recently being associated with phenolic compounds, since natural occurring antioxidants have shown to contribute against oxidative damage caused by free radicals. Lattanzio (2003) stated that phenolic compounds showed health promoting properties of fruits including beneficial influence also against disease development such as cancer and coronary heart diseases. Useniket et al. (2004) found that the level of susceptibility/tolerance to fungal infections and pests could be determined by phenolic composition of plant tissue.

The total phenol contents of fruit juices were expressed as gallic acid equivalents (GAE) using the Folin-Ciocalteu method. The total phenolic content cultivars vary significantly at $p \leq 0.05$ among mango cultivars (Table 3), and it was on average 4.7% higher in conventional than in organic mango fruits. Cartea et al. (2011) found in their study that maturity stage, environmental conditions, especially light, and mode of fertilization could influence the production of phenolic compounds. Mango cultivars *'Bolibo' and 'Kent'* showed highest value in their total phenolic compounds (3.08 and 3.06 mg 100 ml^{-1} juice). The variation of total phenolic content between mango cultivars

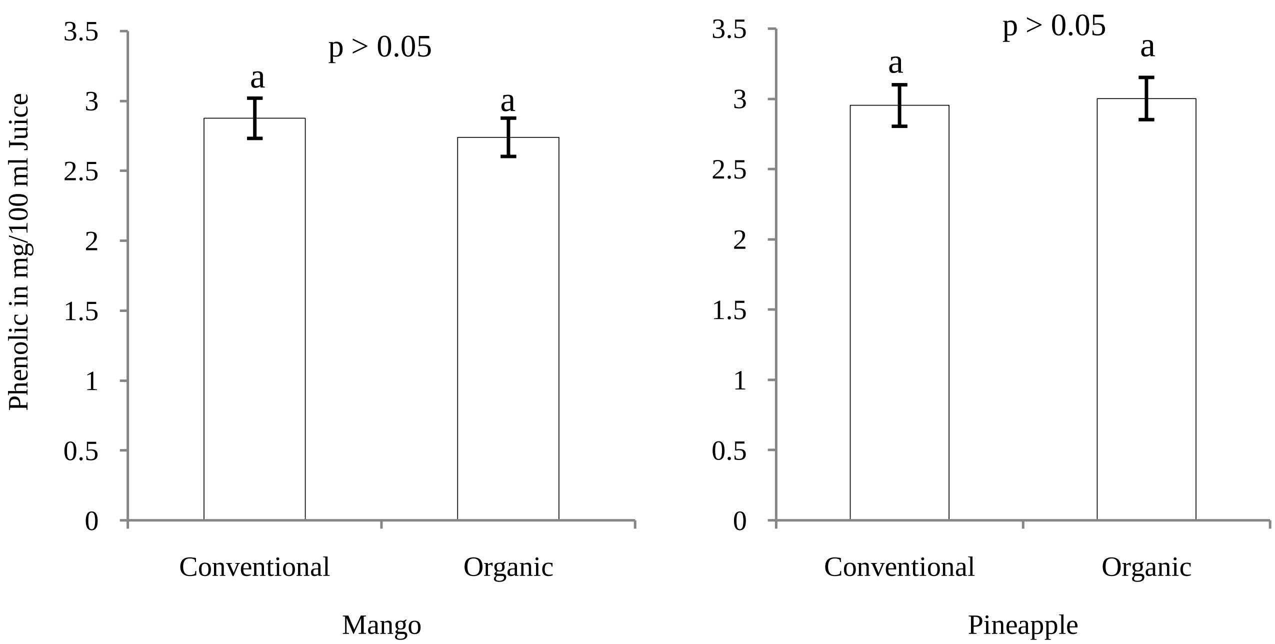

Figure 3. Total phenolic content in mango (n=12) and pineapple fruits (n=16). Values with same letters are not significantly different ($p \geq 0.05$).

could be due the genetic variations, as it is well-known that the biosynthesis of phenolic compounds in plants is strongly influenced by the cultivar (Häkkinen and Törrönen, 2000).

The difference in total phenolic content was not significant ($p \geq 0.05$) among pineapple fruits (Table 3), although organic pineapples have shown 1.7% higher than conventional pineapples in their phenolic contents (Figure 3). Anttonen et al. (2006) observed that the variations of fruit phenolics contents were not signifcant between organic and conventional fruits grown in farms within a similar climatic conditions.

Valavanidis et al. (2009) found in their study that in polyphenol content was similar for both organic and conventionally grown fruits. Other studies done by Veberic and Stamper (2005) found that apple grown organically showed higher content of phenolic compounds in the pulp as compared to conventional apples. Carbonaro et al. (2002) revealed that phenolic substances increase in organic peaches and pear fruit production. This speculates the role of phenolic compound in defence mechanism of plant, due to the fact that in organic agriculture where there is no application of chemical pesticides, plants use their natural compounds to defend themselves against pest and disease.

The method of cultivation and location could contribute to the difference in the total phenolic content of pineapple cultivar '*smooth cayenne*', although, in our study, the effect of conventional and organic production system showed slight influence. This could be due to different soil types and climate condition which these pineapple cultivars were produced. The soils differ in their availability of nutrients to plant due to different agricultural practices which could be influenced by the method of fertilization.

In organic agriculture, nitrogen is realized in the form which could not be readily available to the plant as in conventional agriculture. The availability of nitrogen is important for the production of phenolic compounds as well as, total soluble solids content in plant. Sander and Heitefuss (1998) found in their studies that the increasing nutrient availability to the plant showed decrease in concentration of phenolic compounds. These relationships according to Jones and Hartley (1999) could be explained by different hypothesis, carbon/nutrient balance, growth-differentiation balance and protein competition. It was found by these hypotheses that when the nutrients are more available the plants tend to increase growth and develop more but, on the other hand, the allocation of resources for the production of expendable metabolites like phenolic antioxidants is reduced. In the organic farming system, the slow and prolonged supply of nitrogen does not trigger a spike in plant growth; due to this more photosynthetic sugars could be made available for production of vitamin C and other polyphenols.

Ascorbic acid content

Vitamin C is among the most important vitamins in fruits and vegetables. Fruit and vegetables including the potato

Table 4. Ascorbic acid content in mango and pineapple fruits.

Fruit Mango cultivar	Ascorbic acid content (mg 100g^{-1} juice)	Origin	Production
Dodo	6.02±1.35^{bc}	Tanzania	Organic
Bolibo	2.36±0.15^{d}	Tanzania	Organic
Viringe	2.46±0.21^{d}	Tanzania	Organic
Tommy Atkins	4.97±0.05^{c}	Burkina Faso	Organic
Kent	8.02±2.60^{a}	Costa Rica	Conventional
Kent	6.93±0.91^{ab}	Ivory Coast	Conventional
Kent	8.40±0.72^{a}	Mali	Conventional
Kent	6.00±0.82^{bc}	Peru	Conventional
Pineapple cultivar			
Smooth cayenne	5.60±1.35^{bc}	Tanzania	Organic
Smooth cayenne	7.47±1.91^{ab}	Uganda	Organic
Smooth cayenne	8.92±0.93^{a}	Costa Rica	Conventional
Smooth cayenne	5.00±1.41^{c}	Ghana	Conventional
Smooth cayenne	6.43±0.67^{bc}	Honduras	Conventional

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

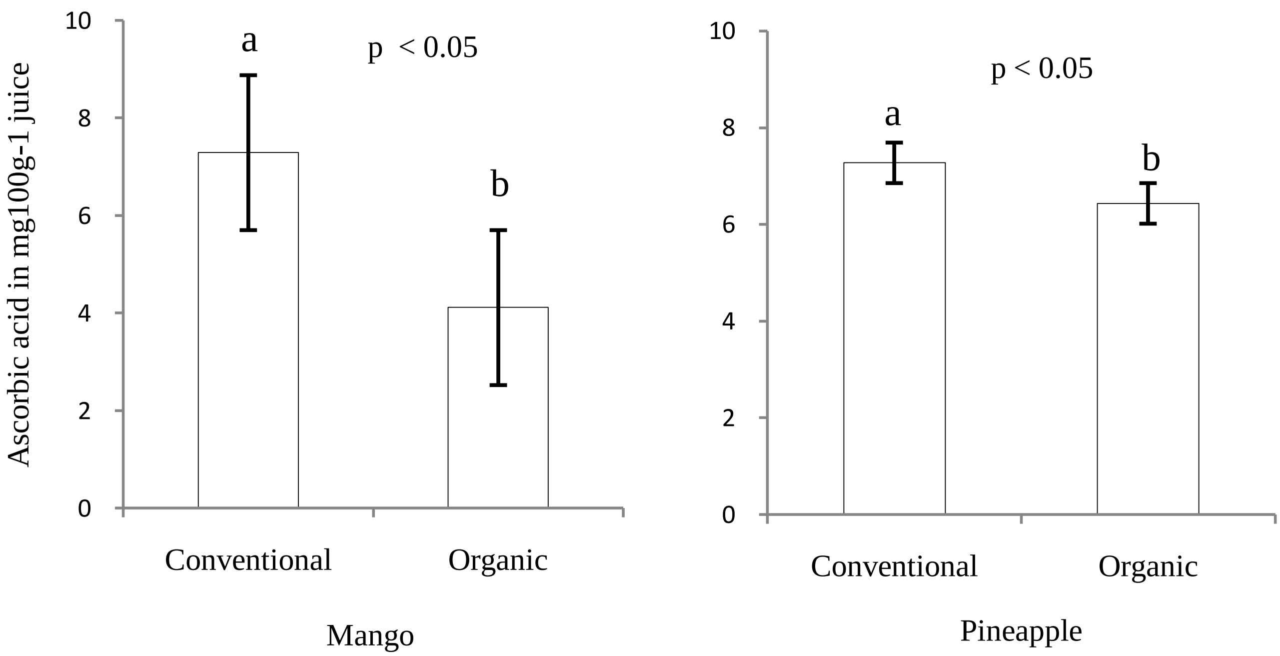

Figure 4. Ascorbic acid content in conventional and organic mango (n=12) and pineapple (n=16). Values with different letters are significantly different ($p \leq 0.05$).

supply more than 90% of the vitamin C in the human diet (Hiza and Bente, 2007). Vitamin C of the horticulture crops could be affected by many pre- and post-harvest factors (Lee and Kader, 2000). Fruit is a better source of antioxidants, flavonoids, phytochemicals and minerals (Ismail and Fun, 2003). Odriozola-Serrano et al. (2007) mentioned that vitamin C is an important antioxidant present in fruits and vegetables. According to Hernández et al. (2006), vitamin C is an additive of processed foods (Rios and Penteado, 2003).

In Table 4, the ascorbic acid content varied significantly among the mango cultivars. Conventionally grown mango showed on average 43.5% higher ascorbic content than organically grown mango fruits (Figure 4). The levels of ascorbic acid in conventional production system showed that mango cultivar '*Kent*' grown in different location varied significantly, suggesting the effect of location due to soil type and climatic condition. The mango cultivars '*Kent*' from a conventional production system showed higher ascorbic content than mango cultivars '*Tommy Atkins*', *'Dodo'*, *'Bolibo'*and*'Viringe'* from an organic production system. The genetic variability as well as, difference in soil type could have an influence on ascorbic acid in mango cultivars

There were significant variations in pineapple cultivars *'Smooth Cayenne'* grown in different location under two production systems as indicated in the Table 4. Ascorbic acid content was 11.5% higher in conventional than in organic pineapple fruits. The variation of ascorbic acid could be due to the difference in both soil type and production method. According to Virginia (2001), nitrogen from any kind of fertilizer affects the amounts of vitamin C and nitrates as well as, the quantity and quality of protein produced by plants. Normally, a high supply of nitrogen increases production of protein at the expense of carbohydrates; as a result, vitamin C will be reduced. High nitrogen fertilization could be associated with a reduction of ascorbic acid (Lee and Kader, 2000). Wang and Lin (2003) found that the use of compost as a soil supplement has significant effects on ascorbic acid. Organically managed soils generally present plants with lower amounts of nitrogen than chemically fertilized soils, as such it would be expected that organic crops would have more vitamin C, less nitrate and less protein, but be of a higher quality than comparable conventional crops. Because our samples were collected from different locations, this might contribute to variation of ascorbic acid. The conventional mango and pineapple fruit showed higher ascorbic acid levels than organic fruits as indicated in Figure 4.

Conclusion

The results of this study indicate that differences in cultivar, type of cultivation, location, and climate can significantly influence the levels of ascorbic acid and the total phenolic contents of fruit. Mango cultivars from different locations showed significant variations in terms of all these variables, while total carotenoids and total phenolic variations were not significant among pineapple cultivars. Organic mango was higher in carotenoids than conventional while total carotenoids content were higher in conventional pineapple, while organic and ascorbic acid was higher in conventional than organic for both mango and pineapple. Antioxidant capacity in both mango and pineapple fruit varied between cultivars, locations and cultivation methods.

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