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Msoka, Regina

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Physio-chemical properties of five cashew apple (*Anacardium occidentale* L.) varieties grown in different regions of Tanzania

Regina Msoka[1,2], Neema Kassim[*1], Edna Makule[1], Peter Masawe[2]

[1]*Department of Food Biotechnology and Nutrition Sciences, Nelson Mandela African Institution of Science and Technology (NM-AIST), Arusha, Tanzania*

[2]*Naliendele Agricultural Research Institute, Newala Road, Mtwara, Tanzania*

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Abstract

Cashew apple fruits are deserted by majority of cashew nuts producers despite of being rich in useful nutrients namely vitamins, minerals and sugar. This study was carried out to determine the physical-chemical properties of five cashew apple varieties from Mtwara and Lindi regions in south-eastern part and Coast region in eastern part of Tanzania. Cashew apple varieties named B.D, AC4, AC10, AZA2 and AZA17 were selected and analysed for vitamin C, carotenoids, total sugar, total phenolic content (TPC), minerals, pH, total soluble solids (TSS) and total titratable acidity (TTA) using standard methods and procedures. Significant different ($p < 0.05$) was observed in vitamin C, total sugar, TPC, TSS and TTA between the five varieties and sites with the content ranging from; Vitamin C (253.09-348.54mg/100ml), total sugar (88700–219400mg/L), TPC (1066.55 – 2886.67 mg/L GAE), TSS (14.94 - 20.36 °Brix) and TTA (0.18% - 0.72%). Other parameters, pH and carotenoids differed significantly between varieties ($p < 0.001$) but there was no significant different observed between sites with content ranging from; carotenoids (5.51-12.74mg/L), pH (3.87-5.09). Minerals (Ca^{2+}, K^{+}, Mg^{2+}, Na^{+}, P^{3-} , Fe^{2+}, Zn^{2+} and Cu^{2+}) content differed significantly between varieties and sites ($p < 0.05$), except for Calcium, Magnesium and Sodium. These results have availed the potential nutritional value of locally available cashew apple fruits to food and nutrition security if well promoted for utilization.

* **Corresponding Author:** Neema Kassim ✉ neema.kassim@nm-aist.ac.tz

Introduction

Cashew tree (*Anacardium occidentale* L.) is native to the northern and north-eastern regions of Brazil (Assunc and Mercadante, 2003). It bears cashew nut and cashew apple, accounting for 10% and 90% of the total fruit weight respectively (Talasila and Shaik, 2013) and (Deenanath *et al.*, 2015). Cashew apples are elongated, round or pear-shaped fibrous fruits. The fully developed cashew apple is firm and juicy. They are rich in sugar, vitamins, minerals, amino acids, carotenoids and phenolic compounds (Marc *et al.*, 2012; Gordon *et al.*, 2012). They are also classified based on their cultivar and colour being red, orange, yellow or greenish-yellow.

While cashew nut is commonly consumed worldwide (Fontes and Honorato, 2009; Sivagurunathan *et al.*, 2010), cashew apple is often considered as a by-product, large part of it being wasted or left to rot under the trees after the nuts have been harvest. Only small proportion of cashew apples are processed into variety of products such as juice, jams, wines, candies and animal feed (Akinwale, 2000; Campos *et al.*, 2002; Attri, 2009; Dedehou *et al.*, 2015) in well industrialized countries such as Brazil. The fruits are challenged with acidity, high perishability and astringent test causing irritation of the tongue and throat, leading to unpalatable and biting sensation when eaten (Gordon *et al.*, 2012; Shaik and Talasila, 2013). In addition, properties of fruits are attributed by several factors like type of soil on which cashew is cultivated, climate of an area, ecological zone and the environment (Talasila and Shaik, 2013).

In Tanzania, 70% of cashew nut is produced in Mtwara, 18% in Lindi, 4% in Ruvuma and 8% in cost region (Masawe *et al.*, 2013), contributing to 497.4 billion to Tanzanians economy in 2015 equivalents to 10.97% from export. Despite being nutritious, cashew apples have not been marketed as fresh fruits neither processed into value added products in Tanzania. Only few farmers have reported to use cashew apples in distilling strong local brew known as "*uraka*" in Swahili (Kasuga, 2013). On the other hand, this fruit is hampered by poor processing technology to produce safe and quality product for the domestic and international market.

The underutilization emanates from in one arm, the lack of facts on its importance in food and nutrition security to attract consumer's interest as well as poor postharvest handling and value addition technologies of perishables. Therefore, the aim of this study was to understand the nutritive value of five commonly grown cashew apple varieties in different regions of Tanzania to look-over the possibility of utilizing them.

Materials and methods

Study site and design

Cashew apples were obtained from three cashew growing sites owned by Naliendele Agricultural Research Institute (NARI's) of Tanzania. These sites are located at Mkuranga (7°08' 11" S, 39°11' 24" E; 131 metres above sea level (masl) in coastal region in eastern part of Tanzania, Naliendele (10°22' 22" S, 40°09' 35" E; 102 masl) in Mtwara region and Nachingwea (10°19' 46" S, 38°46' 46" E; 442 masl) in Lindi region both in south-eastern part of Tanzania. Split plot design was used with block variety divided into three equal plots, and then samples were randomly collected in each plot.

Sample collection

Cashew apples from five cashew varieties named Brazilian dwarf (B.D), Anacardium Ceylon 4 (AC4), Anacardium Ceylon 10 (AC10), Anacardium Zanzibar 2 (AZA2) and Anacardium Zanzibar 17 (AZA17) which are commonly grown by cashew farmers in Tanzania were used in this study. A total of 45 composite samples were collected, 15 and 3 samples from each site and variety respectively. Optimal ripe, intact cashew apples were handpicked, packed in a cool box and transported to the Nelson Mandela African Institution of Science and Technology (NM-AIST) laboratory for juice extraction and analysis.

Sample preparation and juice extraction

Cashew apples were detached from the nut, washed with distilled water, air dried and then weighed. They were then cut into small pieces, blended (Waring Commercial Laboratory blender, USA), and then filtered through Muslim cloth. The juice was collected into a clean flask and then stored at -20°C prior to analyses.

Analysis of Cashew Apple Juice

Determination of pH, total titratable acidity and total soluble solids

pH was determined using a pH-meter (Orion star A214, Indonesia) calibrated at three buffer solutions of pH 4, 7 and 10. Total Titratable Acidity (TTA) as percent of citric acid was determined by placing 10mL of cashew apple juice in a beaker and titrated against 0.1 M sodium hydroxide solution until the end point at pH 8.2 (Nielsen, 2010; Adou *et al.*, 2012).

$$\% \, Citric\, acid = \frac{0.1 M\ NaOH\ X\ volume\, of\ NaOH\ (in\, litres)\ X\ 192.43^{*} g / moles}{3\ X\ weight\, of\ sample} X\ 100$$

192.43*g/moles = Molecular weight of citric acid Total soluble solids (TSS) was determined by using a hand-held model refractometer (Ref 201 Salinity 0-100, Germany) equipped with a digital display and expressed as °Brix (Adou *et al.*, 2012).

Determination of sugar content

Ten millilitre of cashew apple juice was clarified by centrifugation (Eppendorf Centrifuge 5430 R, Germany) at 7500rpm for 5 minutes. 1mL of supernatant was diluted with distilled water 100 times and then total sugar content was determined by phenol sulphuric acid method as described by (Du Bois *et al.*, 1956). Briefly 2mL of the diluted sample was pipetted to a 15mL test tube; 50 µl of 80% w/v phenol was added followed by 5mL of concentrated H_2SO_4 after 15 minutes and allowed to stand for 10 minutes at room temperature and then placed for in a water bath at 27°C for 15 minutes. The absorbance of the mixture was measured at 485nm and the concentration in mg/L (ppm) of the sample was estimated using calibration curve of the standard glucose.

Determination of Vitamin C content

Vitamin C content was determined by Spectrophotometric method based on coupling reaction of 2, 4-dinitrophenylhydrazine dye (Kapur *et al.*, 2012; Mussa and Sharaa, 2014). 5mL of sample was mixed with 20mL of 5% metaphosphoric acid – 10% acetic acid solution, filtered using what man filter paper (No. 1, 125mm diameter) and centrifuged at 4000rpm (Universal 320 Hettich-Zentrifugen, Germany) for 15 minutes. 4mL of the supernatant was placed in a falcon tube.

Few drops of bromine water were added to the supernatant until colour changed to faint orange brown, which confirm complete oxidation of L-ascorbic acid to dehydroascorbic acid. To obtain a clear solution few drops of 10% thiourea solution were added to remove excess of bromine and then 1mL of 2, 4-dinitrophenylhydrazine solution was added. The mixture was kept in a thermostatic bath at 37°C for 3 hours and then cooled in an ice bath for 30 minutes and then treated with 6 mL chilled 85% sulphuric acid (H_2SO_4), with constant stirring. As a result, a red colored solution was formed. Absorbance of the prepared sample was measured at 521 nm using ultraviolet visible spectrophotometer (UV-Vis) (2800 UV/VIS Spectrophotometer, UNICO-spectrophotometer, USA). Vitamin C (mg/100ml) content was then estimated based on the standard curve of ascorbic acid measured at 521nm.

Determination of Carotenoids contents

Carotenoid content of cashew apple juice was determined by the method of extraction using water-miscible solvents as previously described by (Perez-lopez, 2010). 10mL of cashew apple juice was mixed with 20mL of extracting solvent; hexane: acetone: ethanol (2:1:1 v/v/v) in a separating funnel and then 20mL of 10% NaCl was added to aid phase's separation. Upper phase containing carotenoid was recovered and transferred to a falcon tube, dried over anhydrous sodium sulphates (Na_2SO_4) and then its absorbance was measured at 450nm. Carotenoid (mg/L) content was then estimated based on the standard curve of β-carotene measured at 450nm.

Determination of Tannins contents

Tannins content was estimated as the difference between total phenolic and non-tannin phenolic content in the cashew apple juice. Total phenolic content in cashew apple juice was determined in terms of Gallic acid equivalents (GAE) using Folin Ciocalteu method (Singleton and Rossi, 1965) with slightly modification. 1mL of extracted cashew apple juice was diluted with distilled water to 10mL. An aliquot (0.1mL) from the diluted sample was mixed with 1mL of distilled water, 0.5mL of Folin Ciocalteu to 2N reagent and then left in contact for 3 minutes.

Then 3mL of 2% (w/v) Na_2CO_3 were added and the solution was centrifuged at 3000rpm for 15 minutes. Absorbance of the sample was measured at 750 nm using ultraviolet visible spectrophotometer (UV-Vis) (2800 UV/VIS Spectrophotometer, UNICO-spectrophotometer, USA). Total phenolic content was then calculated based on the standard curve of Gallic acid and expressed as mg/L of Gallic acid equivalent (GAE).

To determine non-tannin phenolic content, 1mL of the diluted juice sample was mixed with 1mL of distilled water and 100mg polyvinyl-polypirrolidone (PVPP). The mixture was vortexed, left for 15 minutes at 4°C and then centrifuged for 10 minutes at 3000 rpm. Non- tannin phenolic content in the supernatant was determined in the way similar to the total phenolics content.

Analysis of Mineral content of cashew apples

Atomic absorption spectrophotometric method was used to analyse minerals except Phosphorus (P^{-3}) according to the method reported by (Roos and Price, 1970). 20mL of cashew apple juice was treated with 10mL of 3 M HNO_3 in conical flask and then placed for digestion in the Orbital flasks shaker (KIKA-WERKE Co. KS 501 Digital made in Germany) at 220rpm for 30 minutes.

The mixture was filtered into 100mL flat bottomed flask, adjusted to the mark by deionized water and then analysed using atomic absorption spectrophotometer (AAS) (Younglin AAS 8010 made in Korea). Phosphorus was analysed using colorimetric method (Zalba and Galantini, 2007). Quantification of minerals (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, Cu^{2+}, Fe^{2+}, Zn^{2+} and P^{-3}) was done on the basis of their standard curves.

Statistical analysis

Data were analysed by two-way analysis of variance (ANOVA) with the Genstat statistical package 2014 version. All measurement were obtained in triplicate and expressed as mean value ± standard error of the mean (SEM). Significant between the mean values was detected by applying Duncan Multiple Range Test (DMRT) at $p < 0.05$.

Results and discussion

pH, total titratable acidity and total soluble solids of selected cashew apple

The findings of this study indicated that, pH values differed significantly ($p < 0.001$) between cashew apple varieties. When comparing the same variety between sites, there was no significant variation on pH (Table1), implying that, sites had no influence on pH content of the fruit. These results revealed the acidic nature of these cashew apples fruits in all the varieties analysed, AZA2 variety from the site of Naliendele being the most acidic with pH value (3.87) and AZA 17 the less acidic with pH value (5.09).

Similar findings were found in previous research work, whereby they found pH of the cashew apples to range from 4 to 4.74 (Lowor and Agyente, 2009; Adou *et al.*, 2012 and Naka *et al.*, 2015)

Total Titratable acidity (TTA) of cashew apples ranged from 0.18 - 0.72% for B.D from Mkuranga and AZA2 from Nachingwea respectively, (Table 1). This result implies that fruits used for analysis were at optimal maturity stage. This is due to the fact that as the degree of maturity of fruit is higher than the acid content becomes lower. In this study, the levels of TTA found in cashew apples from Nachingwea correspond with those reported by (Adou *et al.*, 2012), ranging from 0.5-0.85%.

Total soluble solids (TSS) of cashew apple juice varied from 14.9-20.36°Brix as obtained from AZA17 yellow variety from Mkuranga and B.D red variety from Nachingwea respectively, (Table 1). The analysis of variance revealed that, site had significant influence on the level of TSS among varieties analysed which is attributed by the nature of soils and climates.

Unlike findings from this study where there was no clear trend on TSS content between red and yellow varieties, Naka *et al.*, (2015) reported levels of TSS being higher (14.40±0.10°Brix) in yellow variety than in red variety (9.66±0.28°Brix). Similarly, Adou *et al.*, (2012) reported 10.2°Brix and 10.9°Brix in red and yellow varieties respectively.

Table 1. Physiol-chemical properties and composition of cashew apple varieties from Mkuranga, Nachingwea and Naliendele.

Site	Variety	Color of the cashew apple	Storage at 4°C prior to analysis (days)	Total sugar (mg/L)	pH	Total soluble solids(°Brix)	TTA (%)
Mkuranga	AC10	Red	5	$88759±2969.09^{e}$	$4.39±0.09^{bcd}$	$15.17±0.85^{e}$	$0.2±0.03^{ab}$
	AC4	Red	3	$129280±7537.22^{c}$	$4.32±0.02^{bcde}$	$17.07±1.29^{bcde}$	$0.29±0.02^{cd}$
	AZA17	Yellow	6	$103519±3982.35^{de}$	$4.45±0.04^{b}$	$14.94±0.61^{e}$	$0.18±0.02^{a}$
	AZA2	Greenish-yellow	4	$125537±8929.83^{cd}$	$4.15±0.06^{cde}$	$15.49±0.83^{de}$	$0.22±0.02^{abc}$
	BD	Red	3	$139192±2269.52^{c}$	$4.35±0.15^{bcde}$	$17.07±1.29^{bcde}$	$0.18±0.02^{a}$
Nachingwea	AC10	Red	7	$173180±9148.54^{b}$	$4.2±0.06^{bcde}$	$17.07±0.86^{bcde}$	$0.57±0.03^{f}$
	AC4	Red	8	$167823±8683.66^{b}$	$4.2±0.05^{bcde}$	$16.47±0.98^{cde}$	$0.47±0.01^{f}$
	AZA17	Yellow	6	$178508±12739.58^{b}$	$4.32±0.09^{bcde}$	$16.61±0.56^{cde}$	$0.42±0.04^{ef}$
	AZA2	Greenish-yellow	5	$178578±15955.23^{b}$	$4.06±0.17^{ef}$	$18.37±0.8^{abc}$	$0.72±0.04^{g}$
	BD	Red	4	$190589±2718.96^{b}$	$4.28±0.01^{bcde}$	$20.36±0.62^{a}$	$0.61±0.02^{g}$
Naliendele	AC10	Red	7	$91151±3271.65^{e}$	$4.11±0.06^{def}$	$17.94±0.24^{abcd}$	$0.44±0.01^{f}$
	AC4	Red	8	$93046±11608.85^{e}$	$4.43±0.05^{bc}$	$14.56±0.11^{e}$	$0.35±0.03^{de}$
	AZA17	Yellow	6	$187718±7368.83^{b}$	$5.09±0.02^{a}$	$15.23±0.05^{e}$	$0.27±0.01^{bc}$
	AZA2	Greenish-yellow	5	$215818±10976.41^{a}$	$3.87±0.14^{f}$	$18.48±1^{abc}$	$0.49±0.04^{f}$
	B.D	Red	4	$219414±5945.61^{a}$	$4.17±0.07^{bcde}$	$19.34±0.25^{ab}$	$0.49±0.01^{f}$
Mean				152036	4.29	16.94	0.39
CV%				9.4	3.5	7.9	10.7
P - value (site)				***	ns	**	***
P – value (Variety)				***	***	***	***
P - value (Site x Variety)				***	***	*	***

Value with similar superscripts arranged vertically is not significantly different from each other ($p > 0.05$) in the same site and between sites. Values are expressed as mean ± SEM, TTA: Total titratable acidity; ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$ and ns: not significant.

Total sugar content

Sites and varieties had a very high significant influence ($p < 0.001$) on the total sugar content of cashew apples. The overall mean level of total sugar ranged from 88,759– 219,414mg/L as obtained from AC10 variety from Mkuranga and B.D variety from Naliendele sites respectively, (Table 1). Maximum total sugar content was observed in B.D cashew apple variety from Naliendele (219,414mg/L), the closer higher value was found in AZA2 cashew apple variety from Naliendele (215,818mg/L) followed by B.D variety from Nachingwea (190,589mg/L). In case of sites, Naliendele has shown to be the leading site with high content of sugar followed by Nachingwea and Mkuranga. These variations may be attributed by the environmental and genotypic factors as well as the hydrolysis of polysaccharides into simple sugar during ripening stage (Naka *et al.*, 2015).

The types of sugar could be glucose, fructose and sucrose as they have been reported to be the major sugar found in cashew apples (Sivagurunathan *et al.*, 2010; Adou *et al.*, 2012). Except for AC4 and AC10 varieties from Naliendele, total sugar found in cashew apples from Nachingwea and Naliendele were higher than those of 162,700-168,100mg/L as reported by (Adou *et al.*, 2012).

Also, total sugar of cashew apples from all sites, were higher than those of 8,840–14,450mg/L as reported by (Lowor and Agyente, 2009).

Vitamin C content of cashew apple juice

Vitamin C contents of the selected cashew apple are shown in Table 2. Values ranged from 253.09-348.54mg/100 mL were observed in the site of Naliendele and Mkuranga for AC4 variety respectively. This variation gives the significant effects of site, interaction of site by variety ($p < 0.001$) and variety ($p < 0.05$) on vitamin C content. Highest vitamin C content was observed in AC4 cashew apple variety from Mkuranga (348.54mg/100 mL), and the closer higher value was found in the same variety from Nachingwea (303.49mg/100 mL). This was not the case for AC4 variety from Naliendele (253.09mg/100 mL) which was the lowest compared to other varieties in the same site and in the other two sites. Variations due to sites could be attributed by environmental and soil factors and the interaction between these factors and the individual variety (Geddeda and Belal, 2014). Also differences in the storage time at low temperature after harvest and prior analysis could be another factor for variations between varieties and sites. Lee and Kader, (2000) reported significant effects of storage temperature and time on vitamin C content in vegetables and fruits.

The values obtained were lower than the results reported by (Adou *et al.*, 2012) ranging from 370.9-480.3mg/100g in cashew apple samples of Yamoussoukro (Côte d'Ivoire). However, our results were within the ranges of vitamins C in cashew apples previously reported by (Lowor and Agyente, 2009; Daramola, 2013).

Vitamin C values obtained in this study were much higher compared to other tropical fruits like orange, grape, pineapple, mango and lemon which contain an average values of 54.7, 45.0, 14.70, 30.9 and 33.7mg/100mL vitamin C of juice, respectively (Akinwale, 2000). This supports the potentiality of cashew apple as the major source of vitamin C as compared to other tropical fruits. Vitamin C obtained in this study per each apple ranged between (16.87-23.24)mg. This can be used to supplement the RDA of children (1-6 years and 7-9 years), adolescents (10-18 years) and adults (19-65 years) which are 30mg/day, 35mg/day, 40mg/day and 45mg/day respectively (FAO/WHO, 2005).

Carotenoids content of cashew apple juice

In all sites, levels of carotenoids were higher in the red coloured cashew apples from cashew varieties named AC10 (12.13-12.72), AC4 (9.72–12.74) and B.D. (9.83–10.6)mg/L as compared to yellow coloured cashew apple variety, AZA17 (7.79–9.14) mg/L and greenish-yellow cashew variety, AZA2 (5.51–6.4)mg/L.

No statistical significant effect ($p > 0.05$) of site on the carotenoid content was observed, the variation showed statistical significant effect ($p < 0.001$) of variety on carotenoid content, Table 2. The variation might be due to the genotypic effect of the cultivar. These results are consistent with results reported by (Assunção and Mercadante, 2003a,b) found in cashew apple samples from different regions of Brazil.

Table 2. Physio-chemical properties and composition of cashew apple varieties from Mkuranga, Nachingwea and Naliendele.

Site	Variety	Color of the cashew apple	Storage at 4°C prior to analysis (days)	Vitamin C (mg/L)	Carotenoids (mg/L)	TPC (mg/L) GAE	TC (mg/L) GAE
Mkuranga	AC10	Red	5	330.06 ± 10.65^{ab}	12.72 ± 0.36^{a}	2406.21 ± 101.72^{b}	931.61 ± 128.16^{ef}
	AC4	Red	3	348.54 ± 0.56^{a}	9.72 ± 0.66^{c}	2296.44 ± 19.54^{b}	1361.50 ± 2.88^{g}
	AZA17	Yellow	6	323.59 ± 8.77^{bc}	9.14 ± 0.81^{cd}	2886.67 ± 77.59^{a}	1757.47 ± 35.75^{h}
	AZA2	Greenish-yellow	4	330.59 ± 11.91^{ab}	5.51 ± 0.55^{f}	1406.21 ± 10.92^{f}	882.76 ± 31.03^{e}
	BD	Red	3	341.17 ± 4.80^{ab}	9.83 ± 0.24^{bc}	1591.84 ± 36.78^{de}	376.44 ± 32.76^{bc}
Nachingwea	AC10	Red	7	298.62 ± 9.12^{d}	12.13 ± 0.1^{a}	1701.03 ± 2.30^{d}	974.14 ± 6.32^{ef}
	AC4	Red	8	303.46 ± 2.26^{d}	12.74 ± 0.23^{a}	1941.26 ± 54.06^{c}	947.89 ± 51.94^{ef}
	AZA17	Yellow	6	306.94 ± 1.01^{cd}	7.93 ± 0.11^{d}	2407.93 ± 174.71^{b}	1042.14 ± 26.19^{f}
	AZA2	Greenish-yellow	5	257.24 ± 1.38^{f}	6.4 ± 0.19^{ef}	1440.69 ± 85.63^{ef}	594.25 ± 40.23^{d}
	BD	Red	4	266.4 ± 6.26^{ef}	10.54 ± 0.9^{bc}	1683.22 ± 79.89^{d}	357.47 ± 33.52^{b}
Naliendele	AC10	Red	7	256.35 ± 0.17^{f}	12.42 ± 0.39^{a}	2024.41 ± 33.57^{c}	911.49 ± 39.66^{ef}
	AC4	Red	8	253.09 ± 3.31^{f}	11.34 ± 0.37^{ab}	1915.40 ± 121.26^{c}	1295.40 ± 77.01^{g}
	AZA17	Yellow	6	258.87 ± 3.03^{f}	7.79 ± 0.49^{de}	1948.74 ± 43.1^{c}	1387.76 ± 12.64^{g}
	AZA2	Greenish-yellow	5	265.53 ± 1.7^{ef}	5.97 ± 0.77^{f}	1066.55 ± 72.41^{g}	502.30 ± 45.98^{cd}
	B.D	Red	4	279.61 ± 5.28^{e}	10.6 ± 0.33^{bc}	1688.39 ± 38.86^{d}	151.73 ± 24.13^{a}
Mean				294.70	9.65	1893.57	907.66
CV%				3.6	8.7	5.6	11.5
P - value (site)				***	ns	***	***
P - value (Variety)				*	***	***	***
P - value (Site x Variety)				***	**	***	***

Value with similar superscripts arranged vertically is not significantly different from each other ($p > 0.05$) in the same site and between sites. Values are expressed as mean ± SEM, TPC: Total phenolic contents; TC: Tannin content; GAE: Gallic acid equivalent; ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$ and ns: not significant.

Total phenolic content and tannins content

The findings from this study indicated that site, variety and their interaction had a very high significant influence ($p < 0.001$) on the total phenolic and tannin content obtained. The overall mean level of total phenolic content ranged from 1066.55mg/L - 2886.67mg/L GAE as obtained from AZA2 variety from Naliendele and AZA17 variety from Mkuranga respectively, (Table 2). With respect to sites, AZA17 variety has being found to contain higher phenolic content in the site of Mkuranga (2886.67 mg/L GAE) and Nachingwea (2407.93mg/L GAE) in comparison to other varieties within site while in the site of Naliendele three varieties; AZA17 (1948.74mg/L GAE), AC10 (2024.41mg/L GAE) and AC4 (1915.40mg/L GAE) had higher values of phenolic content over the other two varieties; AZA2 and B.D within site. This variation is influenced by genetic and environmental factors as it has been reported by (Bravo, 1998). Phenolic compounds are also considered important as they possess antioxidant and anti-inflammatory properties (Zhang *et al.*, 2011). Similar findings were also recorded in some previous studies (Lowor and Agyente, 2009; Marc *et al.*, 2012; Naka *et al.*, 2015).

Tannins being the major phenolic compound in the cashew apple fruits (Michodjehoun-mestres *et al.*, 2009), its content in this study ranged from 151.73-1757.47mg/L GAE for B.D cashew apple variety from Naliendele and AZA17 cashew apple variety from Mkuranga respectively, (Table 2). Minimum tannin content was found in the B.D variety (151.73 - 376.44 mg/L) in all sites and the closer minimal value in AZA2 variety (502.30-882.76mg/L) in all the sites, implying that these varieties are good for technological processing, since tannins are mostly responsible for the astringency taste of the cashew apple and its juice, hence low preference and consumption especially where the processing technologies are not well advanced.

Tannins content found in this study were relatively low as compared to those reported by (Naka *et al.*, 2015) ranging from 1081.99-2561.61mg/L GAE except for AZA17 and AC4 varieties from Mkuranga and Naliendele. On the other hand, tannins content found in this study were relatively higher compared to those of other fruits such as; banana (3.4mg/100g) and apple (8.5mg/100g) reported by (Obion *et al.*, 2007).

Mineral Composition

Contents of eight minerals analysed in the cashew apple fruits are presented in Table 3. There were statistical significant ($p < 0.05$) differences in mineral contents between varieties and sites except for Ca^{2+} Mg^{2+} and Na^{+}. The prominent elements in all samples were Ca^{2+} and K^{+} ranging from 85–144.52mg/L and 67.31–72.56mg/L respectively. Significant contents of Mg^{2+} and Na^{+} were also found in all cashew apple samples. Other elements such as P^{3-} , Zn^{2+}, Cu^{2+} and Fe^{2+} were observed in very small amount in all samples probably due to the facts that, these minerals were not plenty in the soil. According to (Vesk and Allaway, 1997) large amount of minerals in a plant is commonly attributed by the environmental factors including air, water and the soil where the plant grows.

Minerals play an important role in the human body. Potassium contributes to the maintenance of cell organization and permeability, calcium plays an important role in the growth of skeletal tissue, in the metabolic regulations of bio-molecules as coenzymes, magnesium is involved in nervous system stability and muscle contraction and iron is the most important element in the prevention of anemia, and it is a core element of red blood cells (Ismail *et al.*, 2011).

The levels of the selected minerals in this study were lower than those reported by (Lowor and Agyente, 2009; Marc *et al.*, 2011) except for Na^{+}, Zn^{2+} and Fe^{2+} which were relatively higher than those reported by (Lowor and Agyente, 2009). Na^{+} content was similar to that reported by (Marc *et al.*, 2011).

Table 3. Mineral composition of selected cashew apple varieties from Mkuranga, Nachingwea and Naliendele.

Site	Variety	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	K^{+} (mg/L)	Na^{+} (mg/L)	P^{3-} (mg/L)	Cu^{2+} (mg/L)	Zn^{2+} (mg/L)	Fe^{2+} (mg/L)
Mkuranga	AC10	106.19 ± 2.27^{cde}	34.87 ± 0.27^{cde}	70.83 ± 0.5^{cd}	33.13 ± 0.43^{bcd}	5.96 ± 0.15^{cde}	0.47 ± 0.07^{cde}	2.19 ± 0.24^{cd}	4.11 ± 0.46^{ab}
	AC4	105.71 ± 4.18^{cde}	35.49 ± 0.08^{bcde}	70.94 ± 0.3^{cd}	33.03 ± 0.75^{bcd}	5.89 ± 0.18^{cde}	0.37 ± 0.00^{cdef}	2.23 ± 0.08^{cd}	3.27 ± 0.32^{bc}
	AZA17	99.76 ± 0.24^{e}	35.27 ± 0.36^{bcde}	70.55 ± 0.29^{cd}	32.97 ± 0.97^{bcd}	5.3 ± 0.11^{def}	0.49 ± 0.09^{bcd}	2.02 ± 0.04^{cd}	4.49 ± 0.23^{ab}
	AZA2	104.52 ± 2.08^{de}	34.64 ± 0.48^{de}	70.17 ± 0.03^{d}	32.27 ± 0.79^{cd}	6.37 ± 0.33^{bcd}	0.32 ± 0.02^{efg}	1.98 ± 0.21^{cd}	4.36 ± 0.44^{ab}
	BD	85 ± 2.89^{f}	33.86 ± 0.18^{e}	67.31 ± 0.23^{e}	29.44 ± 0.7^{e}	8.94 ± 1.54^{a}	0.04 ± 0.02^{i}	2.14 ± 0.15^{cd}	4.41 ± 0.35^{ab}
Nachingwea	AC10	98.81 ± 2.27^{e}	36.51 ± 0.1^{abc}	71.49 ± 0.35^{bc}	33.12 ± 0.58^{bcd}	7.35 ± 0.80^{b}	0.22 ± 0.04^{fgh}	2.46 ± 0.19^{bcd}	0.42 ± 0.19^{e}
	AC4	110.71 ± 7.04^{bcde}	35.25 ± 1.62^{bcde}	72.37 ± 0.38^{ab}	33.47 ± 0.09^{bc}	6.89 ± 0.13^{bc}	0.11 ± 0.00^{hi}	2.56 ± 0.17^{bc}	5.52 ± 0.95^{a}
	AZA17	102.38 ± 3.31^{de}	36.55 ± 0.1^{abc}	71.47 ± 0.2^{bc}	32.34 ± 0.27^{cd}	7.04 ± 0.22^{bc}	0.11 ± 0.11^{hi}	2.36 ± 0.13^{bcd}	4 ± 0.49^{b}
	AZA2	103.1 ± 7.48^{de}	36.86 ± 0.5^{ab}	71.42 ± 0.31^{bc}	34.34 ± 0.37^{ab}	6.82 ± 0.57^{bc}	0.19 ± 0.05^{ghi}	2.28 ± 0.14^{bcd}	1.67 ± 0.46^{de}
	BD	115.71 ± 7.70^{bcd}	37.67 ± 0.29^{a}	72.56 ± 0.35^{a}	35.26 ± 0.81^{a}	6.25 ± 0.00^{bcde}	0.19 ± 0.00^{ghi}	3.59 ± 0.1^{a}	4.49 ± 0.66^{ab}
Naliendele	AC10	120.24 ± 1.56^{b}	35.57 ± 0.05^{bcde}	71.48 ± 0.11^{bc}	32.53 ± 0.29^{bcd}	5.04 ± 0.45^{ef}	0.66 ± 0.05^{b}	2.84 ± 0.37^{b}	0.53 ± 0.08^{e}
	AC4	110 ± 0^{bcde}	35.27 ± 0.46^{bcde}	71.36 ± 0.46^{c}	32.58 ± 0.58^{bcd}	2.02 ± 0.08^{h}	0.35 ± 0.08^{defg}	2.27 ± 0.01^{bcd}	2.21 ± 0.61^{cd}

Site	Variety	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	K^{+} (mg/L)	Na^{+} (mg/L)	P^{3-} (mg/L)	Cu^{2+} (mg/L)	Zn^{2+} (mg/L)	Fe^{2+} (mg/L)
	AZA17	119.52 ± 3.51^{bc}	35.95 ± 0.01^{bcd}	71.35 ± 0.11^{c}	31.5 ± 0.18^{d}	5.09 ± 0.04^{def}	0.52 ± 0.02^{bc}	2.12 ± 0.02^{cd}	1.62 ± 0.33^{de}
	AZA2	133.1 ± 5.9^{a}	35.35 ± 0.25^{bcde}	70.33 ± 0.18^{d}	32.67 ± 0.51^{bcd}	3.81 ± 0.45^{g}	0.35 ± 0.13^{defg}	1.94 ± 0.25^{d}	0.61 ± 0.23^{e}
	B.D	144.52 ± 2.12^{a}	36.41 ± 0.05^{abc}	70.9 ± 0.38^{cd}	31.92 ± 0.4^{cd}	4.17 ± 0.23^{fg}	1.19 ± 0^{a}	1.9 ± 0.08^{d}	0.79 ± 0.29^{e}
Mean		110.62	35.70	70.97	32.70	5.80	0.37	2.33	2.83
CV%		6.7	2.5	0.8	3	11.9	23.2	13.6	26
P - value (site)		***	***	***	***	***	***	***	***
P - value (Variety)		ns	Ns	***	ns	**	***	**	***
P - value (Site x Variety)		***	*	***	***	***	***	***	***

Value with similar superscripts arranged vertically is not significantly different from each other ($p > 0.05$) in the same site and between sites. Values are expressed as mean ± SEM, Ca: Calcium; Mg: Magnesium; K: Potassium; Na: Sodium; P: Phosphorous; Cu: Copper; ***: $p < 0.001$; **: $p < 0.01$; *: $p < 0.05$ and ns: not significant.

Conclusions

Physical-chemical analysis of five selected cashew apple varieties from three cashew apple growing sites in eastern and south-eastern part of Tanzania has revealed potential nutritional benefit of this fruit in terms of vitamin C, sugar, minerals and carotenoids. All varieties showed statistical significant variation ($p < 0.05$) in all the parameters measured except for Mg^{2+}, Ca^{2+} and Na^{+}. The results showed that, cashew apples are rich in vitamin C compared to other tropical fruits, and therefore can be used as an alternative to daily supplementation for vitamin C in children and adults. Furthermore, the levels of sugars in cashew apples are a good substrate to supporting fermentation for the production of wine, alcohol and vinegar. Therefore, the current study has availed the potential contribution of locally available, neglected cashew apple to food and nutrition security if well promoted for utilization.

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