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Assessment of physical chemical parameters of cashew apples from selected cashew varieties grown in Tanzania

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ASSESSMENT OF PHYSICAL CHEMICAL PARAMETERS OF CASHEW APPLES FROM SELECTED CASHEW VARIETIES GROWN IN TANZANIA

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Life Science of the Nelson Mandela African Institution of Science and Technology

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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 physico-chemical parameters 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 Brazilian dwarf (B.D), Anacardium Ceylon 4 (AC4), Anacardium Ceylon 10 (AC10), Anacardium Zanzibar 2 (AZA2) and Anacardium Zanzibar 17 (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 difference ($p < 0.05$) 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 - 348.54 mg/100 ml), total sugar (88.7 – 219.4 g/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 difference observed between sites. 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. In Chambezi- Bagamoyo site, varieties differed significantly in all the parameters analysed except for vitamin C, pH, total soluble solids and all the minerals analysed except Ca^{2+}. These results have availed the potential nutritional value of locally available cashew apple fruits to food and nutrition security if well promoted for utilization.

DECLARATION

I, **Regina J. Msoka** do here declare to the Senate of Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being concomitantly submitted for degree award in any other institution.

Signature____________________ Date____________________

Regina J. Msoka

The above declaration is confirmed

Signature____________________ Date____________________

Dr. Neema Kassim (Supervisor 1)

Signature____________________ Date____________________

Dr. Edna Makule (Supervisor 2)

Signature____________________ Date____________________

Prof. Peter Masawe (Supervisor 3)

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CERTIFICATION

The undersigned certify that, they have read the dissertation titled, "**Assessment of Physical Chemical Parameters of Cashew Apples from Selected Cashew Varieties Grown in Tanzania"** and recommend for examination in fulfillment for the requirements for the degree of Master's in Life Science of the Nelson Mandela African Institution of Science and Technology.

Signature____________________ Date____________________

Dr. Neema Kassim (Supervisor 1)

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Dr. Edna Makule (Supervisor 2)

Signature____________________ Date____________________

Prof. Peter Masawe (Supervisor 3)

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DEDICATION

This work is dedicated to my beloved husband Philimon Elias Philipo, my children (Noreen and Philibert), my parents Mr. and Mrs John Francis Msoka and Mr. and Mrs Elias Philipo for their love, support, encouragement and motivation to my academic achievements.

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LIST OF ABBREVIATIONS AND SYMBOLS

>	Greater than
≥	Greater or equal to
<	Less than
AC10	Anacardium Ceylon 10
AC4	Anacardium Ceylon 4
AZA17	Anacardium Zanzibar 17
AZA2	Anacardium Zanzibar 2
B.D	Brazilian Dwarf
CV	Coefficient of Variation
%	Percentage
ANOVA	Analysis of Variance
Ca	Calcium
Na	Sodium
Mg	Magnesium
K	Potassium
Zn	Zinc
Fe	Iron
P	Phosphorus
Cu	Copper

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Cashew tree (Anacardium occidentale L.) is native to the northern and north-eastern regions of Brazil (Assunção and Mercadante, 2003a). It belongs to the Anacardiaceae family, concentrated in the tropical region of the globe and is widespread in several countries such as Brazil, India, Mozambique, Tanzania, Kenya, Vietnam, Indonesia, Thailand, Nigeria, Cote D'Ivoire, Ghana, Gambia, Guinea Bissau, Sri Lanka and Senegal (Paiva et al., 2009; Lima et al., 2014; Masawe and Kapinga, 2016).

It bears cashew nut and cashew apple, accounting for 10% and 90% of the total fruit weight respectively (Talasila and Shaik 2013; 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). Additionally, they are classified based on their cultivar and colour being red, yellow, orange or greenish-yellow.

Cashew nuts are commonly consumed worldwide (Fontes and Honorato, 2009; Sivagurunathan *et al.,* 2010) while cashew apples are often considered as a by-product, large part of them being wasted or left to rot under the trees after the nuts have been harvest. In well industrialized countries like brazil and India, it is reported that, 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). 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; Talasila and Shaik, 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. 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 product 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 set the basis for value addition of cashew apple fruits by understanding physical chemical parameters of five commonly grown cashew apple varieties in different regions of Tanzania and to suggest the best varieties to be used in optimizing processes.

1.2 Problem statement and justification

In Tanzania more than 80% cashew farming relies on cashew nuts as an economic important crop; overlooking the importance of cashew apple fruits which are left in the field as waste products. The nutritional composition of cashew apple and its usage in developing variety of products like juice, jam, wine, candies and animal feed made out of waste products in countries like Brazil and Ghana have been reported, thus they are regarded as a source of employment and income generation (Akinwale, 2000; Attri, 2009).

In Tanzania, farmers may chew the apple fruits by the way as an entertainment or as a means to reduce hunger while working in the field. Very few farmers have reported to use cashew apples in distilling strong local brew known as "*uraka*" in Swahili (Kasuga, 2013). Fresh cashew apples have not been marketed as fresh fruits neither have been processed into value added products given its high perishability.

Naliendele Agricultural Research Institute (NARI) has realized the importance of unveiling the potential of underutilized cashew apple fruits in addition to the nuts in the cashew farming in Tanzania. To set basis for value addition, it is of equal importance to profile the physical- chemical parameters that are known to positively or negatively affect the quality of the cashew apple products.

1.3 Research objectives

1.3.1 General objective

The general objective of this research work was to assess cashew apple physical-chemical parameters which may influence the quality of cashew apple value added products and to ascertain suitable variety of cashew apple for juice processing.

1.3.2 Specific objectives

i. To develop a nutritional profiling of cashew apple from five selected cashew grown varieties.
ii. To analyse the tannins content of cashew apples from the selected cashew varieties that affects the quality of cashew apple products.

1.4 Research questions

i. What is the nutritional composition of different cashew apple varieties?
ii. What is the level of tannins found in cashew apple fruits?

1.5 Significance of the study

This study has developed a nutritional profile of cashew apple composition and identifying the level of tannins present in cashew apple fruits. The results provide a baseline of optimizing process for value addition of these fruits, hence making variety of products like juice, jam and wine.

These products may contribute to a healthy diet of the consumers, income generation of the cashew growers in addition to cashew nut. Addition to that may create new agricultural and industrial employment opportunities.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cashew apple

2.1.1 Description of cashew apple

Cashew apple is the pseudo-fruit of the cashew tree, is an oval or pear-shaped accessory fruit or false fruit that develops from the receptacle of the cashew flower (Masawe and Kapinga, 2016).

A fully developed cashew apple fruit is a thin-skinned edible fruit likely to be firm, juicy and easily detachable from the nut. It is at this stage that flavor, aroma and sugar concentrations are maximum and acidity and astringency are minimum (Figueiredo *et al*., 2002). Its flesh can be eaten raw or processed into variety of products. Ripe cashew apple may be yellow, greenish yellow, red or orange.

A: Red cashew apples
B: Yellow cashew apples
D: Greenish-yellow cashew apples
D: Orange cashew apples

Figure 1: Cashew apples attached to the nut

2.2 Nutritional composition of cashew apple

2.2.1 Vitamins

Vitamins are group of organic compounds, essential for normal functioning of the human body and are broadly distributed in natural food sources. Vitamins are classified into two groups basing on their solubility, fat soluble vitamins (vitamin A, D, E and K, also included carotenoids) and water soluble vitamins (vitamin C and members of vitamin B group namely thiamine; vitamin B_1, riboflavin; vitamin B_2, Niacin, vitamin B_6, folate and vitamin B_{12}).

The major vitamin found in cashew apple fruits is vitamin C. Vitamin C in cashew apple is relatively higher compared to other tropical fruits.

Table 1: Vitamin C content (mg/100 ml) of cashew apple in comparison to other tropical fruits in Nigeria (Akinwale, 2000).

Commodity	Total vitamin C (mg/100g)
Cashew apple	203.5
Orange	54.7
Pineapple	14.7
Lemon	33.7
Grape	45.0
Mango	30.9

It is observed that cashew apple contains the highest amount of vitamin C, approximately four times the amount of vitamin C in the popular citrus fruits and even more than that in other fruits. Cashew apple also contains other vitamins in small quantity like riboflavin, thiamine, niacin and carotenoids (a precursor of vitamin A) (Talasila and Shaik, 2013).

2.2.2 Minerals

Minerals are inorganic nutrients necessary for the maintenance of certain physicochemical processes which are essential to life. Minerals are broadly classified as macro (major), micro (trace) elements and ultra-trace elements (Soetan *et al*., 2010). Mineral analyses performed on cashew apples by different researchers showed the presence of; calcium, sodium, magnesium, potassium, copper, zinc, phosphorus, iron, sulphur, silicon, chlorine, aluminium and bromine (Lowor and Agyente-Badu, 2009; Marc *et al.*, 2011).

2.2.3 Carbohydrates

Carbohydrates are a major class of naturally occurring organic compounds with the general formula of $C_n (H_2O)_n$ with n equals to or greater than three. The well-known carbohydrates are; sugars, starches, and cellulose, all of which are important for the maintenance of life in both plants and animals.

Literature data revealed that, the major carbohydrate found in cashew apple is sugar; glucose, fructose and sucrose (Sivagurunathan *et al.,* 2010; Adou *et al*., 2012).

2.2.4 Protein

Proteins are complex organic compounds made up of chain of amino acids. They provide energy to the body and also used by the body to build and repair tissues. Again protein is used to make enzymes, hormones, and is an important building block of bones, muscles, cartilage, skin, and blood. In cashew apple protein content is reported to be very minimal amount ranging from 0.51 to 0.53 g/100g. Major amino acids found are leucine, cystein and asparagines (Adou *et al*., 2012).

2.2.5 Dietary fibres

Dietary fibre is the indigestible parts of plant foods, such as vegetables, fruits, grains, beans and legumes. It is type of a carbohydrate that helps keep our digestive systems healthy. It is divided into two main groups, soluble fibre and insoluble fibre.

Dietary fibres in cashew apple, has being found to be 209 g kg^{-1} d.m, most of it being insoluble dietary fibre (88%). This content is in the same range as the values reported for some common fruits such as apples, oranges and bananas, in which it ranges from 170 to 360 g kg^{-1} d.m. (Rufino *et al*., 2010).

2.3 Phytochemical composition of cashew apple

2.3.1 Phenolic compound

Phenolic compounds are a large class of plant secondary metabolites, showing a diversity of structures, from simple structures, phenolic acids, through polyphenols such as flavonoids.

Phenolic compounds found in cashew apples fruits are quercetin, naringenin, caffeic acid, coumaric acid, ferulic acid and gallic acid (Marc *et al*., 2012). These compounds possess antioxidants (Dai and Mumper, 2010) and anti-inflammatory activity (Zhang *et al*., 2011).

2.3.2 Tannins

These are polyphenols with the molecular weights ranging from ≥ 500 to ≥ 3000 g/moles. Have the property of binding proteins forming tannin-protein complexes which can reduce or enhance the antioxidant activity of polyphenols and it can also affect the digestion ability of several digestive enzymes present in our body (Suganya and Dharshini, 2011).

Tannins present in cashew apple are mostly responsible for the astringency taste of the apple and its juice hence rendering its normal consumption. They are also known as anti-nutrients by lowering the absorption of some materials into the body. For example, tannins found in tea and coffee hinders the absorption of calcium and iron in the body and often lead to osteoporosis and anemia (Ashok and Upadhyaya, 2012). It is advised to consume food that is rich in vitamin C which helps in neutralizing tannin's effects on iron absorption.

2.4 Applications of cashew apples

Cashew apple fruits contribute to a human nutrition by supplying an adequate daily nutritional requirement for children and adults (Lowor and Agyente-Badu, 2009). Also, they are reported to possess high therapeutic, medicinal properties and used as raw material for many industrial applications (Talasila and Shaik, 2013).

2.4.1 Therapeutic and medicinal properties of cashew apples

Traditionally, cashew apples are used to cure a number of chronic diseases like scurvy, diarrhea, uterine complaints, dropsy, cholera and rheumatism (Attri, 2009). It is also taken as a cure for stomach disorder and is used for treating sore throat infections in Cuba and Brazil.

Many properties of fresh cashew apple juice have been proposed for its therapeutic values like anti-oxidant, anti-fungal, antibacterial, Anti-tumor, anti-inflammatory and anti-mutagenic (Runjala and Kella, 2017). Cashew apples have proved to be very efficient scavengers of peroxyl radicals due to the presence of the various antioxidant compounds such as ascorbic acid, carotenoids, and polyphenols (Cavalcante *et al*., 2003).

2.4.2 Industrial applications

As industrial raw materials cashew apple can be processed into variety of products such as juice, syrup, jam, candy, wine, alcohol, vinegar, dietary fibre, cashew apple pickle, chutney and animal feed made out of waste products (Nwosu *et al*., 2016). They can also be used in fortification of other fruits juices and pulps like lime, pineapple, orange, mango and papaya (Akinwale, 2000). In addition can also be used in sugar separation from cashew apple juice, beverage production, evaluation of yeast strains for ethanol and sugar tolerance, detection of antioxidant properties, and production of vinegar, lactic acid, bio surfactants, dextransucrase, oligosaccharides, and fuel ethanol (Deenanath *et al*., 2015)**.**

2.4.3 Sugar separation

For sugar separation, pure glucose and fructose can be extracted from cashew apple juice by adsorptive chromatography and used for the production of syrups. This type of syrup is an alternative to the present syrup supply from corn hydrolysis (Luz *et al*., 2008).

Production of alcoholic beverages

Cashew wine, an alcoholic beverage, is produced from the fermentation of cashew apple juice. For cashew wine production, the cashew apple juice is fermented using *Sacharomyces cerevisiae* yeasts at temperatures between 28°C and 30°C and pH of 4.0. Alcohol content between 6% (v/v) and 10.6% (v/v) can be obtained (Akinwale, 1999; Araújo *et al*., 2011)

2.4.4 Production of vinegar

Cashew apple juice is a substrate of choice of natural vinegar because of its high sugar content and availability. Vinegar, as a fermentation product from cashew apple juice, its production from cashew apple juice involves the action of S. cerevisiae yeasts on the sugary juice substrate to ethanol, followed by the conversion of the ethanol by acetic acid bacteria to produce acetic acid or vinegar (Deenanath *et al*., 2015)

2.4.5 Cashew apples as bio surfactants

Bio surfactants are products that are derived from plant biomass or vegetable oils by the use of microorganisms. Structurally, bio surfactants are made up of hydrophilic and hydrophobic components. The hydrophilic component consists of amino acids and polysaccharides and the hydrophobic component consists of lipids. This structure enables the bio surfactant molecule to function as emulsifying, foaming, and detergent agents. Bio surfactants are less toxic products and are environmentally safe and degradable (Rocha *et al*., 2006).

Cashew apple juice can be used as a substrate to produce a bio surfactant. The process of bio surfactant production involve, fermentation process of cashew apple juice at a temperature of 30 °C and pH of 7.0, with the action of *Acinetobacter calcoaceticus* to produce an emulsion bio surfactant.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

3.1.1 Chemicals and reagents

These were as summarized in Table 2.

Table 2: Chemicals and Reagents

Name of chemical/Reagent	**Manufacturers**
Folin and Ciocalteu's Phenol reagent (2N)	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Sodium carbonate	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Insoluble polyvinylpyrrolidone (PVPP)	Merck (E. Merck, Darmstadt)
Ethanol	Wagtech Projects LTD. Wagtech Court, Station Road, Thatcham, Berks, RG19 4HZ
Metaphosphoric - acetic acid	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
2, 4-dinitrophylhydrazine	B.D.H Laboratory Chemicals Group in England
Thiourea solution	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Sulphuric acid	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Phenol detached crystals (99.5%) AR/ACS	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Sodium hydroxide	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
pH buffers, 4,7 and 10	Loba Chemie Pvt. Ltd, 107, Wodehouse Road, Jehangir villa, Mumbai-400005. India
Nitric acid	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Hexane	Gato Perez, 33-P.I.Mas d'En Cisa. 08181 Sentimenat SPAIN. Tel. 34-937456400 Made in Spain.
Acetone	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Sodium chloride	Uni-Chem, Chemical Reagents
Sodium sulphate	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Standard beta-carotene	Sigma-Aldrich, Co.3050 Spruce Street, St. Louis Mo 63103 USA.
Standard gallic acid (99.5%) Extra pure	Loba Chemie Pvt. Ltd, 107 Wodehouse Road, Jehangir villa, Mumbai-400005. India
Standard ascorbic acid	Merck Chemicals (Pty) ltd, 259 Davidson Road, Wadeville, Gauteng, RSA
Standard glucose	Merck Chemicals (Pty) ltd, 259 Davidson Road, Wadeville, Gauteng, RSA

3.1.2 Laboratory Equipment

These were as detailed in Table 3.

Table 3: Laboratory equipments

Name of equipment	Model and manufacturer
Centrifuge, 4000 rpm and 7000 rpm	Universal 320 Hettich- Zentrifugen, Germany and Eppendorf Centrifuge 5430 R, Germany
Ultra Violet -Visible spectrophotometer (UV-Vis),	2800 UV/Vis Spectrophotometer, UNICO-spectrophotometer, United State of America
Water bath	S/N A114120801-64 Wagtech Project
pH meter	Orion star A214, Indonesia
Atomic absorption spectrometer (AAS)	Younglin AAS 8010 made in Korea
Titronic machine	Nr 00679531, Germany
Digestion block (flask shaker)	KIKA-WERKE Co. KS 501 Digital made in Germany
Ice maker machine	Ice maker S/N 14728341 Made in China
Analytical balance	S/N 8332140269 Made in China

3.1.3 Cashew apple fruits

Five cashew apple 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 in Tanzania were used in this study.

3.2 Methods

3.2.1 Study site and design

Cashew apples were obtained from four 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) and Chambez- Bagamoyo (6°31'S and 38°55'E; mals) 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.

3.2.2 Sample collection

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.

Forty five samples were collected from the sites of Naliendele, Nachingwea and Mkuranga, 15 and 3 samples from each site and variety, respectively. Again, 12 samples were collected from the site of Chambezi-Bagamoyo from four varieties (AZA2, AZA17, AC10, and AC4).

3.2.3 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, packed into a clean bottle covered with a bottle top and then stored at -20°C prior to analyses.

3.3 Laboratory analysis of cashew apple juice

3.3.1 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 10 mL 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).

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

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 $^{\circ}$ Brix (Adou *et al*., 2012).

3.3.2 Determination of sugar content

Ten milliliter of cashew apple juice was placed in an eppendorf tube, followed by clarification using centrifuge (Eppendorf Centrifuge 5430 R, Germany) at 7500 rpm for 5 minutes. 1 mL of supernatant was diluted with distilled water 100 times and then total sugar content was determined by phenol sulphuric acid method as described by Dubois *et al.* (1956). Briefly 2 mL of the diluted sample was pipetted to a 15 mL test tube; 50 µl of 80% w/v phenol was added followed by 5 mL 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 485 nm and the concentration in mg/L (ppm) of the sample was estimated using calibration curve of the standard glucose (Appendix 1).

3.3.3 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). 5 mL of sample was mixed with 20 mL of 5% metaphosphoric acid – 10% acetic acid solution, filtered using what man filter paper (No. 1, 125 mm diameter) and centrifuged at 4000 rpm (Universal 320 Hettich- Zentrifugen, Germany) for 15 minutes. 4 mL 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 1 mL 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 coloured 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 calculated based on the standard curve of ascorbic acid measured at 521 nm (Appendix 1).

3.3.4 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). 10 mL of cashew apple juice was mixed with 20 mL of extracting solvent; hexane: acetone: ethanol (2:1:1 v/v/v) in a separating funnel and then 20 mL of 10% NaCl was added to aid phase's separation. Upper phase containing carotenoids was recovered and transferred to a falcon tube, dried over anhydrous sodium sulphates (Na_2SO_4) and then its absorbance was measured at 450 nm. Carotenoid (mg/L) content was then estimated based on the standard curve of β-carotene measured at 450 nm (Appendix 1).

3.3.5 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 slight modification. 1 mL of extracted cashew apple juice was diluted with distilled water to 10 mL. An aliquot (0.1 mL) from the diluted sample was mixed with 1 mL of distilled water, 0.5 mL of Folin Ciocalteu to 2N reagent and then left in contact for 3 minutes. Then, 3 mL of 2% (w/v) Na_2CO_3 were added and the solution was centrifuged at 3000 rpm 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 (Appendix 1) and expressed as mg/L of Gallic Acid Equivalent (GAE).

To determine non-tannin phenolic content, 1 mL of the diluted juice sample was mixed with 1 mL of distilled water and 100 mg 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.

3.3.6 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). 20 mL of cashew apple juice were treated with 10 mL 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 220 rpm for 30 minutes. The mixture was filtered into 100 mL 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 (Appendix 2).

3.4 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). Significance difference between the mean values was detected by applying Duncan's Multiple Range Test (DMRT) at ($p < 0.05$).

CHAPTER FOUR

RESULTS AND DISCUSSION

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

The findings of this study indicated that, there was a very high significant variation ($p < 0.001$) of pH between cashew apple varieties. When comparing the same variety between sites, there was no significant variation on pH (Table 4), implying that, sites had no influence on pH content of the fruit. The results found in this study concur with the results reported by Lowor and Agyente (2009), Adou *et al*. (2012) and Naka *et al*. (2015) with pH values ranging from 4 - 4.74 except for AZA2 and AZA17 from Naliendele which had the minimum and maximum pH values of 3.87 and 5.09, respectively.

In Chambezi-Bagamoyo site, varieties had no significant effects ($p > 0.05$). pH values ranged from 3.86 – 4.18 (Table 5). This range and the pH value of AZA2 from Naliendele corresponds to those of Osho (1995) who reported pH value of 3.8 in cashew apple samples from Nigeria. Sivagurunathan *et al*. (2010) reported higher pH values found in samples of cashew apple juice from India, ranging from 4.86 to 5.54, which are higher than those found in this study, except for AZA17 from Naliendele. The pH values reflect the acidic nature of the juice, by which based on the current results AZA2 cashew apple juice from Naliendele and varieties from Bagamoyo have shown to be the most acidic.

Total Titratable Acidity (TTA) of cashew apples ranged from 0.18 - 0.72% for B.D from Mkuranga and AZA2 from Nachingwea, respectively (Table 4).

In the site of Chambezi-Bagamoyo, the TTA variation ranged from 0.33 – 0.42 for AZA2 and AC10 varieties, respectively (Table 5).

In this study, the levels of TTA found in cashew apples from Nachingwea (0.42 – 0.72) correspond with those reported by Adou *et al*. (2012), ranging from 0.5 - 0.85%, while values from other sites were lower than those reported in the literature, which implies that fruits used for analysis were at optimal maturity stage.

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. The analysis of variance revealed that, TSS values differed significantly (p <

0.05) between sites and varieties analysed (Table 4). No significant effect of variety analysed on TSS content in the site of Chambez-Bagamoyo was observed (Table 5).

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 and 10.9 °Brix in red and yellow varieties respectively. These values were lower than those found in this study. However, this variation among countries could be attributed to the nature of soils and climates.

4.2 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 88759 – 219414 mg/L as obtained from AC10 from Mkuranga and B.D from Naliendele sites, respectively (Table 4). Sugar content also differed significantly ($p < 0.001$) between varieties analysed in the site of Chambezi-Bagamoyo (Table 5).

These variations may be attributed by the environmental and genotypic factors as well as the hydrolysis of polysaccharides into simple sugars 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 sugars 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. -168. g/L as reported by Adou *et al*. (2012). Also, total sugar of cashew apples from all sites, were higher than those of 8.4 – 14.45 g/L as reported by Lowor and Agyente (2009) though lower than those reported by Naka *et al.* (2015).

Table 4: Parameters of cashew apple varieties from Mkuranga, Nachingwea and Naliendele

Site	Variety	Colour of the cashew apple	Storage at 4ºC prior to analysis (days)	Total sugar (mg/L)	pH	Total soluble solids(°Brix)	TTA (%)
Mkuranga	AC10	Red	5	88 759±2969.09^{e}	4.39±0.09^{bcd}	15.17±0.85^{e}	0.2±0.03^{ab}
	AC4	Red	3	129 280±7537.22^{c}	4.32±0.02^{bcde}	17.07±1.29^{bcde}	0.29±0.02^{cd}
	AZA17	Yellow	6	103 519±3982.35^{de}	4.45±0.04^{b}	14.94±0.61^{e}	0.18±0.02^{a}
	AZA2	Greenish-yellow	4	125 537±8929.83^{cd}	4.15±0.06^{cde}	15.49±0.83^{de}	0.22±0.02^{abc}
	BD	Red	3	139 192±2269.52^{c}	4.35±0.15^{bcde}	17.07±1.29^{bcde}	0.18±0.02^{a}
Nachingwea	AC10	Red	7	173 180±9148.54^{b}	4.2±0.06^{bcde}	17.07±0.86^{bcde}	0.57±0.03^{f}
	AC4	Red	8	167 823±8683.66^{b}	4.2±0.05^{bcde}	16.47±0.98^{cde}	0.47±0.01^{f}
	AZA17	Yellow	6	178 508±12 739.58^{b}	4.32±0.09^{bcde}	16.61±0.56^{cde}	0.42±0.04^{ef}
	AZA2	Greenish-yellow	5	178 578±15 955.23^{b}	4.06±0.17^{ef}	18.37±0.8^{abc}	0.72±0.04^{g}
	BD	Red	4	190 589±2718.96^{b}	4.28±0.01^{bcde}	20.36±0.62^{a}	0.61±0.02^{g}
Naliendele	AC10	Red	7	91 151±3271.65^{e}	4.11±0.06^{def}	17.94±0.24^{abcd}	0.44±0.01^{f}
	AC4	Red	8	93 046±11 608.85^{e}	4.43±0.05^{bc}	14.56±0.11^{e}	0.35±0.03^{de}
	AZA17	Yellow	6	187 718±7368.83^{b}	5.09±0.02^{a}	15.23±0.05^{e}	0.27±0.01^{bc}
	AZA2	Greenish-yellow	5	215 818±10 976.41^{a}	3.87±0.14^{f}	18.48±1^{abc}	0.49±0.04^{f}
	B.D.	Red	4	219 414±5945.61^{a}	4.17±0.07^{bcde}	19.34±0.25^{ab}	0.49±0.01^{f}
Mean				152 036	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)				***	***	*	***

Values with similar superscripts in a column are 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

Table 5: Parameters of cashew apple varieties from Chambezi-Bagamoyo

Site	Variety	Colour of the cashew apple	Storage at 4ºC prior to analysis (days)	Total sugar(mg/L)	pH	Total soluble solids (Brix)	TTA (%)
	AC10	Red	5	118 876±8049.52[b]	3.96±0.05[ab]	15.05±0.43[a]	0.42±0.01[b]
	AC4	Red	3	140 747±7165.25[a]	4.18±0.09[a]	17.32±0.92[a]	0.35±0.03[a]
	AZA17	Yellow	6	98 607±2246.23[b]	3.92±0.11[ab]	15.92±0.6[a]	0.45±0.04[b]
	AZA2	Greenish-yellow	4	141 180±1277.06[a]	3.86±0.05[b]	16.57±0.34[a]	0.33±0.02[a]
	Mean			124 852.63	3.98	16.22	0.39
	CV%			6.2	3.8	7.1	4.9
Bagamoyo	P-value (variety)			***	ns	ns	**

Values with similar superscripts in a column are not significantly different from each other ($p > 0.05$). Values are expressed as mean ± SEM (Standard error of the mean), TTA: Total titratable acidity, ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$ and ns: not significant.

4.3 Vitamin C content of cashew apple juice

Vitamin C contents of the selected cashew apple are shown in Table 6. Values ranging from 253.09 - 348.54 mg/100 mL were observed in the site of Naliendele and Mkuranga for AC4 variety, respectively. This variation gave 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 (348.54 mg/100 mL), and the next higher value was found in the same variety from Nachingwea (303.49 mg/100 mL). This was not the case for AC4 variety from Naliendele (253.09 mg/100 mL), which was the lowest, compared to other varieties in the same site and in the other two sites. In the site of Chambezi – Bagamoyo, there was no significant difference ($p > 0.05$) in vitamin C content between the varieties analysed. The values ranged from 320.45 – 347.3 mg/100 mL (Table 7).

Variations due to sites could be attributed to 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 - 480.3 mg/100 g in cashew apple samples of Yamoussoukro (Côte d'Ivoire). However, our results were within the ranges of vitamins C in cashew apples previously reported (Lowor and Agyente, 2009; Daramola, 2013).

Vitamin C values obtained in this study were higher compared to other tropical fruits like orange, grape, pineapple, mango and lemon, which contain average values of 54.7, 45.0, 14.70, 30.9 and 33.7 mg/100 mL vitamin C of juice, respectively (Akinwale, 2000). This supports the potential 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 is estimated to be 16.87-23.24 mg/100 mL. 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 30 mg/day, 35 mg/day, 40 mg/day and 45 mg/day, respectively (FAO/WHO, 2005).

4.4 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 carotenoids content was observed. The variation showed statistical significant effect ($p < 0.001$) of variety on the carotenoid content (Table 6)**.** This was also observed in the site of Chambezi-Bagamoyo, red cashew apple (AC10) presented the higher values of carotenoids as compared to yellow cashew apples (AZA17 and AZA2) (Table 7) with very strong significant effect ($p < 0.001$) between the varieties analysed.

The variation might be due to the genotypic effect of the cultivar. These results are consistent with results reported by Assunção and Mercadante (2003a) with carotenoid values ranging from 8.2 - 197.8 µg/100 g and (Assunção and Mercadante, 2003b) with carotenoid values ranging from 16.6 - 67.9 µg/100 g found in cashew apple samples from different regions of Brazil.

4.5 Total phenolic and tannins contents

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 1066.55 mg/L – 2886.67 mg/L GAE as obtained from AZA2 variety from Naliendele and AZA17 variety from Mkuranga, respectively (Table 6). 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 (2407.93 mg/L GAE) in comparison to other varieties within site while in the site of Naliendele three varieties; AZA17 (1948.74 mg/L GAE), AC10 (2024.41 mg/L GAE) and AC4 (1915.40 mg/L GAE) had higher values of phenolic content over the other two varieties; AZA2 and B.D within site. In the site of Chambezi-Bagamoyo, there was significant effect of total phenolic content in the varieties analysed, AC4 variety containing the highest value (2196 mg/L GAE), (Table 7).

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 - 1757.47 mg/L GAE for B.D cashew apple variety from Naliendele and AZA17 cashew apple variety from Mkuranga, respectively, (Table 6). 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 - 882.76 mg/L) in all the sites. In the site of Chambezi-Bagamoyo AZA2 variety was also found to contain low content of tannin (779 mg/L GAE) in comparison to other varieties, Table 7.

These results imply that these varieties (AZA2 and B.D) 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 - 2561.61 mg/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 (3.4 mg/100g) and apple (8.5mg/100g) reported by Obion *et al*. (2007).

Table 6: Physical-chemical properties and composition of cashew apple varieties from Mkuranga, Nachingwea and Naliendele

Site	Variety	Color of the cashew apple	Storage at 4ºC 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.

Table 7: Physical-chemical properties and composition of cashew apple varieties from Chambezi-Bagamoyo

Site	Variety	Colour of the cashew apple	Storage at 4ºC prior to analysis (days)	Vitamin C (mg/L)	Carotenoids (mg/L)	Total Phenolic Contents (mg/L)	Tannins Contents (mg/L)
	AC10	Red	5	320.45±18.20[a]	11.12±0.54[a]	2093±57.67[a]	1296±49.85[b]
	AC4	Red	3	335.9±12.57[a]	9.12±0.39[b]	2196±221.08[a]	2024±218.97[a]
	AZA17	Yellow	6	347.3±11.02[a]	8.3±0.55[b]	1874±14.94[a]	1183±23.11[b]
	AZA2	Greenish-yellow	4	332.66±11.41[a]	5.09±0.45[c]	1282±35.63[b]	779±10.99[c]
	Mean			334.08	8.41	1861	1320
	CV%			5.7	9.9	11.5	7.9
Bagamoyo	P-value (variety)			ns	***	*	***

Value with similar superscripts arranged vertically is not significantly different from each other ($p > 0.05$).

Values are expressed as mean ± SEM (Standard error of the mean), ***: $p < 0.001$, **: $p < 0.01$, *: $p < 0.05$ and ns: not significant.

4.6 Mineral composition

Contents of eight minerals analysed in the cashew apple fruits are presented in Table 8. There were statistical significant differences ($p < 0.05$) in mineral contents between varieties and sites except for Ca^{2+} Mg^{2+} and Na^{+}. In the site of Chambezi-Bagamoyo, minerals did not differ significantly between the varieties analysed except for calcium ($p < 0.05$) (Table 9). The prominent elements in all samples were Ca^{2+} and K^{+} ranging from 85 – 144.52 mg/L and 67.31 – 72.56 mg/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 amounts in all samples, probably due to the fact 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.

These 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 8: 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}
	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}
	BD	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 in a column are 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.

Table 9: Mineral composition of cashew apple varieties from Chambezi-Bagamoyo

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)
	AC10	$95.62{\pm}4.02^{a}$	$34.02{\pm}1.86^{a}$	$70.64{\pm}0.07^{a}$	$33.52{\pm}0.2^{a}$	$6.25{\pm}0.44^{a}$	$0.21{\pm}0.08^{ab}$	$2.9{\pm}0.01^{a}$	$6.27{\pm}0.95^{ab}$
	AC4	$74.29{\pm}3.11^{b}$	$35.97{\pm}0.18^{a}$	$71.07{\pm}0.36^{a}$	$33.59{\pm}0.45^{a}$	$7.14{\pm}0.26^{a}$	$0.16{\pm}0.03^{ab}$	$2.72{\pm}0.06^{a}$	$5.43{\pm}0.66^{b}$
	AZA17	$72.83{\pm}1.28^{b}$	$35.93{\pm}0.02^{a}$	$70.73{\pm}0.15^{a}$	$34.68{\pm}0.85^{a}$	$6.94{\pm}0.24^{a}$	$0.05{\pm}0.03^{b}$	$2.69{\pm}0.24^{a}$	$6.44{\pm}0.43^{ab}$
	AZA2	$83.62{\pm}1.22^{a}$	$35.39{\pm}0.38^{a}$	$70.79{\pm}0.67^{a}$	$34.12{\pm}0.99^{a}$	$6.81{\pm}0.33^{a}$	$0.31{\pm}0.02^{a}$	$2.66{\pm}0.21^{a}$	$7.46{\pm}0.27^{a}$
	Mean	81.59	35.33	70.81	33.98	6.79	0.18	2.74	6.40
	CV%	4.7	4.6	1	3.2	7.8	42.8	8.6	14.9
Bagamoyo	P-value (variety)	**	ns	Ns	ns	ns	ns	ns	Ns

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

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Results obtained from the analysis of five selected cashew apple varieties from three cashew apple growing sites (Naliendele, Nachingwea and Mkuranga) in Tanzania has availed potential nutritional value of this fruit in terms of vitamin C, sugar, organic acids, minerals and carotenoids. All varieties showed statistical significant variation in all the parameters measured except for Mg^{2+}, Ca^{2+} and Na^{+}.

In the site of Chambezi - Bagamoyo in which the analysis was carried out separately due to the absence of one variety (B.D), varieties analysed had significant influence on total phenolic, tannin contents, carotenoids, total sugar and titratable acidity. No significant influence of variety on vitamin C, pH, total soluble solids and all the minerals analysed was observed except Ca^{2+} which differed significantly among varieties analysed.

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.

5.2 RECOMMENDATIONS

The findings from this study indicated 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 sugar in cashew apples are a good substrate to support fermentation for the production of wine, alcohol and vinegar.

Also, of the cashew apple varieties collected from all the sites, AZA2 is an appropriate variety for technological processing of cashew apple products if grown in conditions similar to Naliendele and Nachingwea. On the other hand, variety B.D was revealed to contain low levels of total phenolics, tannins, organic acids (TTA) and high content of sugar. In addition, B.D exhibited outstanding quality parameters across sites. Based on results from this study, B.D is considered a useful variety for apple processing. We further recommend that plans on investing in cashew apple processing have to consider selection of suitable varieties and locations for growing the selected varieties.

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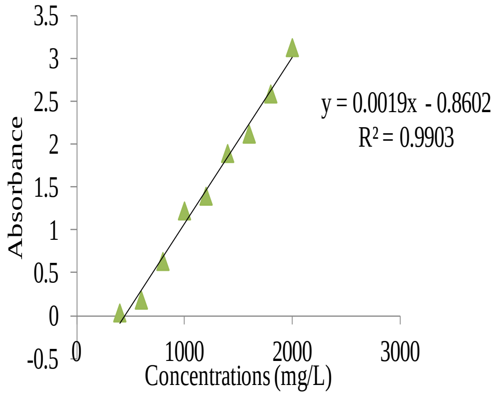
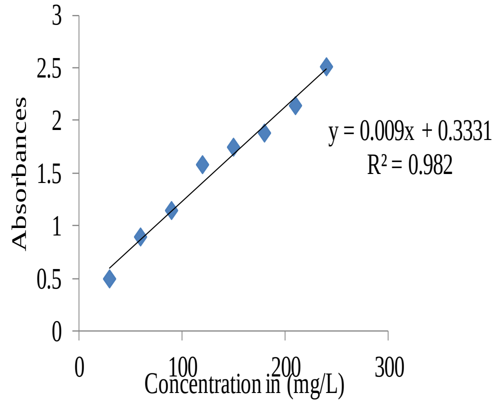
APPENDICES

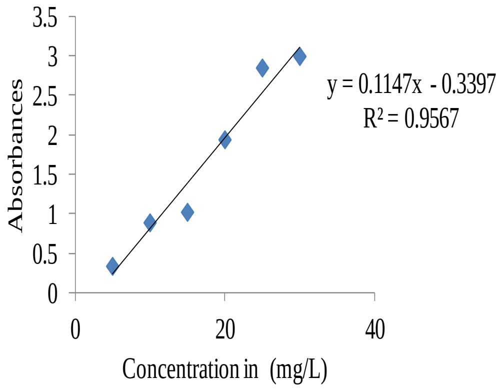
Appendix 1: Standard curves of the parameters analysed, total sugar, vitamin C, carotenoids and total phenolic content



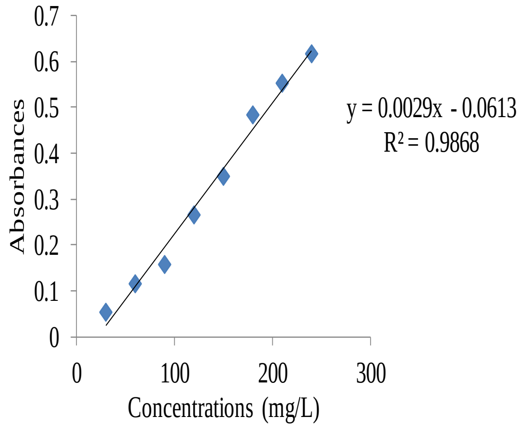
A: Calibration curve of the standard glucose



B: Calibration curve of the standard ascorbic acid

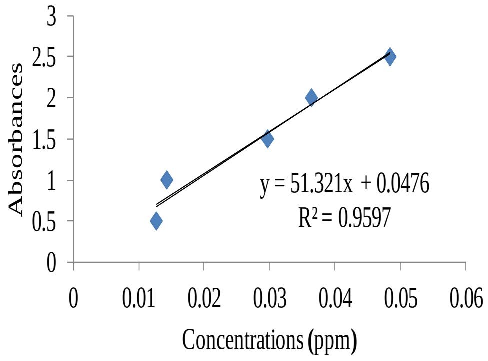


C: Calibration curve of the standard β-carotene

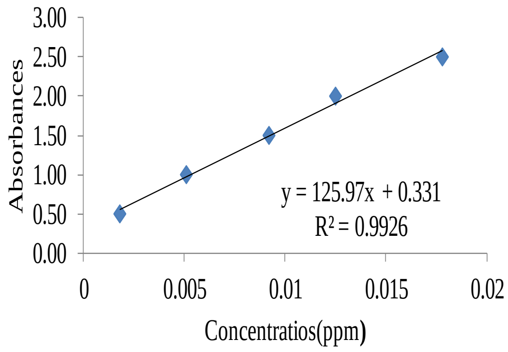


D: Calibration curve of standard Gallic acid

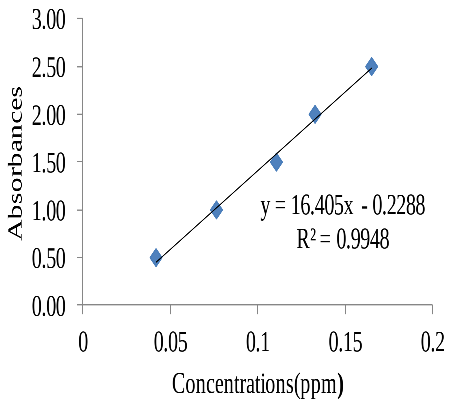
Appendex 2: Standard Curves of the Minerals Analysed



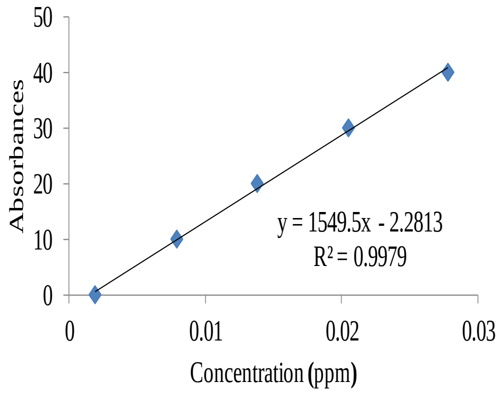
A: Standard curve of copper



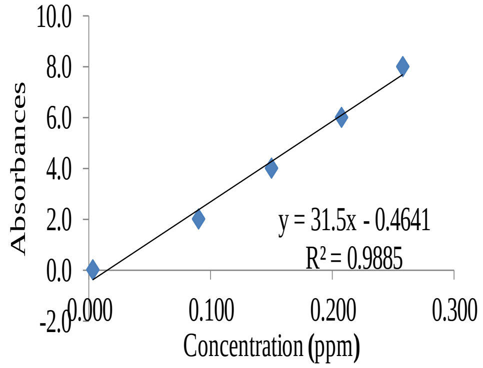
B: Standard curve of Iron



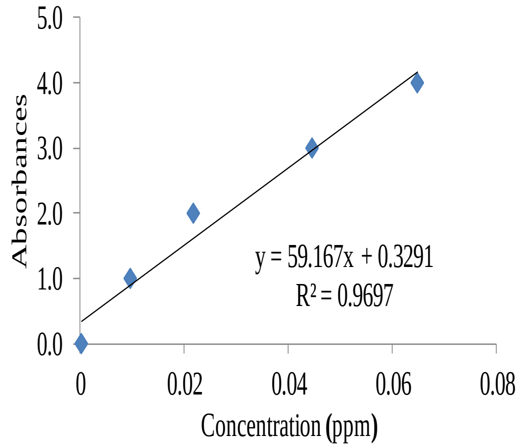
C: Standard curve of zinc



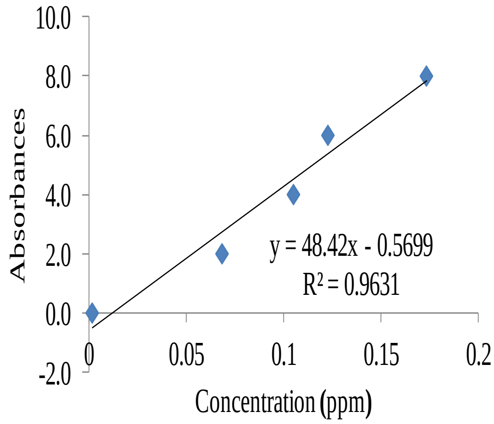
D: Standard curve of calcium



E: Standard curve of magnesium



F: Standard curve of potassium



G: Standard curve of sodium

RESEARCH OUTPUT

Research article

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RESEARCH PAPER OPEN ACCESS

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

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Key words: Cashew apple varieties, sites, physical chemical properties.

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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.

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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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