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PROXIMATE MINERAL COMPOSITION AND VITAMIN C CONTENT OF CASHEW HYBRIDS (Anacardium occidentale L.) IN SOUTHERN AND EASTERN TANZANIA

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ABSTRACT

Proximate composition and mineral concentration of cashew nut grown in two different sites were determined using standard analytical procedures. Nutritional quality characteristics of the genotypes showed variability. Hybrid H1 appeared to be suitable for a number of variables such as protein, fat, potassium, copper, iron, zinc and vitamin C. Hybrids H2, H6, H17, H18 and H22 were the best in iron, zinc and vitamin C contents. Regarding the location, it was observed that Nachingwea kernels were richer than those of Chambezi in zinc and copper while on the other hand Chambezi kernels were richer in the rest of nutritional variables namely crude protein, fat, potassium, magnesium and iron contents.

Keywords: hybrids, nutrition, minerals, vitamin

Introduction

Cashew (*Anacardium occidentale* L.) is a highly nutritious and concentrated form of food, providing a substantial amount of energy. The nut kernel has a pleasant taste and can be eaten raw, fried and sometimes salted or sweetened with sugar (FAO, 1998). In Tanzania, the nut is being considered as the most valuable of the cashew tree even though apples are being consumed as fruits (Masawe, 2006). The cashew nut is a popular dessert nut, eaten out of hand, with other mixed nuts and used in baking and confections. It is high in protein, oil and vitamins such as thiamin, with 47% fat, 21% protein and 22% carbohydrate (Ohler, 1979). The nut can also be made into cashew butter, powder, paste and nut milk. The cashew apple is a pseudo-fruit, the swollen stalk of the true fruit. There are places where people do consume the apple and throw the nut due to its toxicity. The apples are red or yellow in colour, fibrous but juicy, sweet, pungent and high in vitamin A and C. Per 100 g of fresh fruit the cashew apple has more vitamin C than mangoes, oranges and guavas (Davis, 1999). However, only a fraction of cashew apples is used, they are quite perishable and can be used only locally unless preserved. Cashew apple juice is reported to contain five times as much vitamin C as citrus juice (Azam-Ali and Judge, 2001) and ten times as pineapple juice (Ohler, 1979). Those not eaten fresh can be preserved in syrup, candied, sun-dried, stewed and made into juices, chutneys, jams, pickles and vinegar. Within 24 hours after falling from the tree apples start rotting.

Malnutrition refers to deficiencies, excesses or imbalances in a person's intake of energy and/or nutrients. Malnutrition includes both under nutrition and over nutrition. Among the causes of under nutrition include diet lacking in enough of the nutrients (energy, protein, vitamins and minerals) that the body needs for good health (Tanzania Malnutrition Fact Sheet, 2016). Tanzania has one of the highest under nutrition burdens in East and Southern Africa. An estimated 450,000 children in Tanzania are acutely malnourished or wasted, with over 100,000 suffering from the most severe form of acute malnutrition (ESA, 2017). Proteins that are essential to growth and health are currently required more in developing countries of the world, because of prevalent outbreak of protein-energy malnutrition in these countries (FAO, 1997).

Several studies have shown nuts to be a rich source of nutrients, mainly protein, fat, vitamins, as well as minerals such as P, K, Mg, Fe (Rodushkin *et al.* 2008 and Sathe *et al.* 1997). Consequently, nuts have been recognized as important sources of some essential elements (e.g. B, Se, Cu, Zn, Fe and Mn) in human nutrition (Cabrera *et al.* 1995 and Nascimento *et al.* 2010).

Materials and methods

Experiments were conducted during the 2014/2015 cropping season in the Southern (Nachingwea) and Eastern (Chambezi) zones of Tanzania. Nachingwea is located at 10°20'S, 38°46'E, altitude 465 m above sea level. The rainfall pattern is mono modal (December to April) with an annual average of about 877 mm (Masawe *et al.*, 2015). The average temperature for the year at Nachingwea is 24.4°C and the average humidity ranges from 54 to 78% (weather base, 2011). Soils at Nachingwea are red or reddish-brown sandy loams and loams. Chambezi is located at 6°31'S, 38°55'E and altitude 33 m above sea level. Rainfall ranges between 800 and 1200 mm per annum (District Profile 2006, Mushi 2009) which is very high compared to Nachingwea. The district has seasonal average temperatures ranging from 13°C to 30°C and humidity recording as high as 98% (EPMS, 2006). Dominant soil types include sand, loam, sandy-loam and clay (District profile 2006).

Twenty nine selected elite cashew hybrids planted in 2005 (H1, H2, H3, H4, H5, H6, H7, H8, H9, H10, H11, H12, H13, H14, H15, H16, H17, H18, H19, H21, H22, H23, H24, H25, H26, H27, H28, H29 and H30) and a registered cashew variety AC4 was used as a control in this study. Two kilograms of nuts collected from each hybrid in each location were opened and kernels subjected to protein, fat and mineral concentration determination. Fat content was determined by Soxhlet Continuous Extraction method while protein content by Kjeldalh method. For mineral determination, a sample of kernel powder (each 5 g) was put in crucibles and burned

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in blast furnace at 500^oC for 3 hours to destroy organic matter. After burning, ashes were allowed to cool. Then each sample was dissolved in 10 ml of dilute hydrochloric acid (1:1 = HCl: H_2O ratio = 6 N) and stirred thoroughly. The dissolved content was filtered with a filter paper placed in filter funnel. The filtrate was collected in a conical flask then transferred into 100 ml volumetric flask. Distilled water was added into the filtrate to make up 100 ml volume of the filtrate ready for mineral determination. Calcium and magnesium concentration was measured using atomic absorption spectrum at wavelength 422.7 nm and 285.2 nm, respectively. Concentration of potassium and sodium was determined using flame photometer at 766.5 nm and 589.0 nm, respectively. The Atomic Absorption Spectrophotometer (AAS) was also used to determine concentration of iron, zinc and copper. The AAS was set at the wavelengths of 248.3 nm for iron, 324.8 nm for copper and 213.9 nm for zinc.

For vitamin C determination, fruits from each plot in each replication to represent a single hybrid was collected in each site, sorted, washed with clean water, macerated and the juice sieved (cheese cloth) using sterile equipment and thereafter frozen at -20°C until analysed. Vitamin C was determined by iodine titration (AOAC, 2000).

Results and discussion

Results of the nutritional contents and subsequent statistical analyses are presented in Tables 1 - 6. Table 1 shows analysis of variance results for the nutritional variables. Varietal effects on crude protein, fat, potassium, copper, magnesium, iron, zinc and vitamin C were generally found to be highly significant ($P \leq 0.001$). No significant variation was observed in terms of calcium content except for the hybrids at Nachingwea. On the other hand, there was no significant variation in terms of sodium content among the treatments in both sites. The influence of genotypes in nutrients accumulation or deposition into kernels (or fruits) seemed to be equally pronounced in both locations with exception of potassium and calcium. Contents of both mineral elements were significantly different among the hybrids at Nachingwea but insignificant at Chambezi ($P \leq 0.05$). The combined bi-locational analysis showed that locations had significant effects on nutrient contents of all nutritional attributes with exception of Potassium and Calcium

Table 2 shows mean results of nutrients content of the cashew hybrids at Nachingwea site. Best hybrids at this site (richest in accumulated nutrients) were H14, H12, H15 and H27 for CP, H7 for Fat, H6 and H1 for K, H6 for Mg, H17 for Cu, H1, H11 and H17 for Fe, H13 for vitamin C and H6 for Zn. For each nutritional attribute these hybrids were significantly better than many other hybrids as shown in Table 2.

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The mean results of nutrients content of the cashew hybrids at Chambezi site is shown in Table 3. Best hybrids at this site were H18, H16 and H25 for CP, H23, H13 and H25 for Fat, H30 for K, H21 for Mg, H30 for Cu, H8 for Fe, H23 for vitamin C and H12 for Zn.

Table 4 shows mean results of nutrients content of the cashew hybrids in combined analysis. Best hybrids were H15 and H16 for CP, H10, H16, H25 and H22 for Fat, H1, H6, H30, H25 and H19 for K, H25 and H6 for Mg, H17 for Cu, H17 for Fe, H23 for vitamin C and H12 for Zn. These hybrids were significantly better in each nutritional attribute than the rest of the hybrids as shown in the Table 4.

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Table 1: Analysis of variance for nutritional variables in cashew hybrids grown at Nachingwea, Chambezi and in the combined analysis

S.V	DF	Mean square ANOVA values									
		%CP	%Fat	%K	Ca	Na	Mg	Cu	Zn	Fe	Vit C
Nachingwea											
REP	2	0.2987	0.00029	0.0032**	89799	19748	0.00059	0.0057*	0.0029*	0.0039	0.1048
HYBRID	29	20.27***	112***	0.0127***	47297*	4402	0.0065***	119***	73.9***	199***	319.88***
Error	58	0.1632	0.00052	0.0004	19774	4534	0.0002	0.0011	0.00081	0.0013	0.1036
Total	89										
Chambezi											
REP	2	0.246	1.561	0.0230*	40034	9363	0.00056	0.0009	0.0012	0.0045*	0.134
HYBRID	29	8.84***	56.007***	0.0041	33043	6144	0.003***	96.7***	21.2***	45.5***	620.09***
Error	58	1.79	1.571	0.0056	47430	3264	0.00085	0.00091	0.0006	0.00098	0.1948
Total	89										
Combined analysis											
S.V	DF	%CP	%FAT	%K	Ca	Na	Mg	Cu	Zn	Fe	Vit C
REP	2	0.042	0.7626	0.0047	22365	27777***	0.00067	0.005**	0.004**	0.0069**	0.0016
HYBRID	29	14.126***	79.36***	0.01***	44851	5392	0.0043***	129***	59.3***	154***	427.38***
LOCATION	1	98.39***	343.44***	1.236***	88516	2378	0.4650***	35.3***	3.39***	640***	78.619***
LOCATION*HYBRID	29	14.98***	89.19***	0.0067**	35489	5154	0.0052***	86.8***	35.8***	89.9***	512.58***
Error	118	0.9715	0.786	0.0033	34854	3855	0.00053	0.001	0.0007	0.001	0.1507
Total	179										

Key: S.V = Source of variation, DF = Degrees of freedom, CP = Crude Protein (%), K = Potassium (%), Ca = Calcium, Na = Sodium, Mg= Magnesium, Cu = Copper, Zn = Zinc, Fe = Iron, Vit = Vitamin, * Significant at $P \leq 0.05$, ** significant at $P \leq 0.01$, *** significant at $P \leq 0.001$

Table 2: Nutritional content (quality) of cashew (nuts or fruits) hybrids at Nachingwea in Southern Tanzania

Hybrid	%CP	% Fat	%K	%Mg	Cu (ppm)	Fe (ppm)	Vit C (mg/100ml)	Zn (ppm)
H1	21.07^{de}	43.77^{k}	0.611^{ab}	0.2189^{cd}	16.19^{k}	55.6^{a}	203.9^{f}	43.46^{c}
H2	16.65^{mno}	38.22^{p}	0.48^{defgh}	0.209^{cdef}	14.55^{m}	43.81^{g}	210.9^{b}	42.03^{f}
H3	20.03^{efgh}	45.08^{i}	0.4485^{fghijk}	0.1833^{cdef}	17.83^{h}	35.96^{i}	194^{k}	37.26^{p}
H4	19.14^{hijk}	38.01^{r}	0.4767^{defghi}	0.1996^{cdef}	18.65^{g}	32.01^{j}	211^{b}	33.91^{s}
H5	22^{bcd}	38.87^{o}	0.5167^{cde}	0.1815^{def}	15.37^{l}	28.09^{k}	195.3^{j}	32.95^{t}
H6	18.52^{ijkl}	43.08^{l}	0.6467^{a}	0.4033^{a}	4.7^{r}	44.18^{f}	204.9^{ef}	47.94^{a}
H7	14^{qr}	50.1^{a}	0.46^{efghij}	0.2085^{cdef}	14.55^{m}	39.88^{h}	196.9^{i}	38.69^{m}
H8	18.03^{kl}	37.42^{s}	0.3885^{kl}	0.171^{ef}	12.91^{n}	35.95^{i}	193.8^{kl}	27.23^{w}
H9	21.64^{cd}	43.01^{l}	0.4485^{fghijk}	0.1893^{cdef}	6.34^{q}	43.8^{g}	196.9^{i}	30.57^{v}
H10	19.61^{ghij}	48.68^{b}	0.41^{ijk}	0.1989^{cdef}	16.19^{k}	32.02^{j}	195.4^{j}	30.57^{v}
H11	15.21^{pq}	36.23^{t}	0.4813^{defgh}	0.2173^{cde}	12.08^{o}	55.6^{a}	200.8^{gh}	42.98^{d}
H12	23.08^{ab}	33.25^{w}	0.5052^{cdef}	0.2266^{cd}	21.11^{e}	55.31^{b}	206.9^{cd}	42.98^{d}
H13	18.35^{jkl}	32.66^{x}	0.4214^{hijk}	0.207^{cdef}	16.19^{k}	32.02^{j}	214.7^{a}	36.3^{q}
H14	23.4^{a}	46.09^{f}	0.4693^{defghi}	0.1972^{cdef}	17.83^{h}	39.88^{h}	167.3^{p}	42.51^{e}
H15	22.79^{abc}	45.34^{h}	0.43^{ghijk}	0.2101^{cdef}	7.16^{p}	39.88^{h}	189.6^{m}	43.46^{c}
H16	20.8^{defg}	45.69^{g}	0.3392^{l}	0.1709^{f}	16.19^{k}	32.02^{j}	181.7^{o}	30.57^{v}
H17	21.12^{de}	29.46^{z}	0.4804^{defgh}	0.2297^{c}	35.06^{a}	55.6^{a}	201.3^{g}	40.6^{j}
H18	19.75^{fghi}	39.79^{n}	0.4591^{efghij}	0.2212^{cd}	21.11^{e}	47.74^{e}	211.5^{b}	41.55^{h}
H19	20.93^{def}	34.89^{u}	0.53^{cd}	0.2057^{cdef}	17.83^{h}	43.81^{g}	207.1^{c}	38.21^{n}
AC4	17.39^{lmn}	47.55^{c}	0.4911^{defg}	0.2^{cdef}	16.53^{j}	43.81^{g}	197.1^{i}	40.12^{k}
H21	18.71^{ijk}	34.84^{u}	0.3975^{jkl}	0.1923^{cdef}	22.75^{d}	35.95^{i}	183.6^{n}	31.53^{u}
H22	18.66^{ijkl}	46.2^{e}	0.4094^{ijk}	0.2011^{cdef}	26.86^{c}	39.88^{h}	205.9^{de}	39.16^{l}
H23	15.83^{op}	34.36^{uv}	0.5052^{cdef}	0.2104^{cdef}	21.11^{e}	43.81^{g}	201.1^{g}	37.73^{o}
H24	16.56^{no}	46.81^{d}	0.4693^{defghi}	0.2144^{cdef}	17.83^{h}	28.09^{k}	204.6^{f}	38.69^{m}
H25	17.95^{klm}	44.48^{j}	0.5686^{bc}	0.35^{b}	18.65^{g}	48.19^{d}	196.6^{i}	41.78^{g}
H26	13.59^{r}	30.09^{y}	0.3975^{jkl}	0.2109^{cdef}	17.01^{i}	32.02^{j}	199.8^{h}	41.07^{i}
H27	22.74^{abc}	41.22^{m}	0.53^{cd}	0.2111^{cdef}	17.83^{h}	39.88^{h}	192.8^{l}	37.73^{o}
H28	17.93^{klm}	32.26^{xy}	0.5035^{cdef}	0.2173^{cde}	18.65^{g}	39.89^{h}	184.4^{n}	44.89^{b}
H29	18^{kl}	38.14^{q}	0.4767^{defghi}	0.21^{cdef}	31.78^{b}	39.88^{h}	207.8^{c}	38.21^{n}
H30	19.64^{fghij}	29.73^{yz}	0.52^{cde}	0.2201^{cd}	20.29^{f}	51.68^{c}	189.8^{m}	35.35^{r}
Mean	**19.1**	**39.84**	**0.48**	**0.22**	**17.7**	**41.21**	**198.25**	**38.33**
SE±	**0.404**	**0.023**	**0.021**	**0.014**	**0.034**	**0.036**	**0.322**	**0.029**
%CV	**2.1**	**0.1**	**4.4**	**6.7**	**0.2**	**0.1**	**0.2**	**0.1**
P-value	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Means with the same superscript letter(s) in the same column are not significantly different ($P \leq 0.05$) following separation by Tukey's Test. Key: CP = Crude Protein (%), K = Potassium (%), Mg= Magnesium, Cu = Copper, Zn = Zinc, Fe = Iron, Vit = Vitamin

Table 3: Nutritional content (quality) of cashew (nuts or fruits) hybrids at Chambezi in Eastern Tanzania

Hybrid	%CP	%Fat	% K	%Mg	Cu (ppm)	Fe (ppm)	Vit C (mg/100ml)	Zn (ppm)
H1	21.85^{abcde}	42.5^{efghij}	0.71^{a}	0.22^{c}	21.33^{e}	44.18^{f}	210.6^{e}	36.39^{l}
H2	21.81^{abcde}	36.49^{lm}	0.64^{a}	0.28^{abc}	19.2^{g}	48.19^{d}	196.7^{k}	34.85^{o}
H3	19.53^{bcdef}	42.9^{defghi}	0.64^{a}	0.34^{ab}	14.95^{k}	44.18^{f}	178^{q}	38.7^{i}
H4	18.55^{def}	40.82^{fghijk}	0.67^{a}	0.28^{abc}	17.08^{i}	44.22^{f}	167.6^{s}	36.01^{m}
H5	18.39^{ef}	42.82^{defghi}	0.61^{a}	0.31^{abc}	12.83^{l}	36.14^{i}	199.5^{j}	35.61^{n}
H6	22.73^{abcd}	39.82^{hijklm}	0.62^{a}	0.28^{abc}	17.83^{h}	44.19^{f}	199.5^{j}	37.16^{k}
H7	19.27^{bcdef}	35.79^{mn}	0.61^{a}	0.2667^{bc}	23.45^{d}	46.18^{e}	188.8^{n}	37.55^{j}
H8	19.45^{bcdef}	46.69^{abcd}	0.56^{a}	0.29^{abc}	8.59^{n}	54.22^{a}	191.2^{m}	36.39^{l}
H9	18.1^{ef}	39.04^{ijklm}	0.63^{a}	0.3033^{abc}	8.58^{n}	40.16^{h}	213.1^{d}	32.54^{q}
H10	20.3^{abcdef}	44.84^{bcdef}	0.64^{a}	0.3367^{ab}	8.58^{n}	44.18^{f}	205.3^{gh}	36.39^{l}
H11	21.81^{abcde}	43.7^{defgh}	0.62^{a}	0.31^{abc}	19.2^{g}	46.18^{e}	171.4^{r}	39.86^{f}
H12	20.24^{abcdef}	39.39^{ijklm}	0.591^{a}	0.34^{ab}	19.2^{g}	46.18^{e}	186.6^{o}	44.48^{a}
H13	21.35^{abcdef}	48.61^{ab}	0.6981^{a}	0.34^{ab}	8.58^{n}	48.19^{d}	199^{j}	38.7^{i}
H14	19.33^{bcdef}	38.42^{klm}	0.5984^{a}	0.3^{abc}	17.08^{i}	46.18^{e}	210.2^{e}	36.01^{m}
H15	22.4^{abcde}	31.77^{n}	0.6316^{a}	0.3367^{ab}	17.07^{i}	42.17^{g}	196.4^{k}	33.31^{p}
H16	23.38^{ab}	47.74^{abc}	0.59^{a}	0.33^{ab}	7.52^{o}	42.17^{g}	211.4^{e}	37.55^{j}
H17	20.35^{abcdef}	40.68^{ghijk}	0.62^{a}	0.32^{ab}	20.27^{f}	50.2^{c}	208.1^{f}	39.86^{f}
H18	24.23^{a}	40.3^{ghijkl}	0.65^{a}	0.3367^{ab}	17.08^{i}	46.18^{e}	204.5^{h}	36.01^{m}
H19	18.11^{ef}	44.73^{bcdef}	0.68^{a}	0.3033^{abc}	16.02^{j}	42.17^{g}	213.6^{d}	39.47^{g}
AC4	20.77^{abcdef}	46.22^{abcde}	0.63^{a}	0.3033^{abc}	24.52^{c}	48.19^{d}	179.5^{p}	37.55^{j}
H21	21.61^{abcdef}	47.74^{abc}	0.639^{a}	0.37^{a}	8.58^{n}	42.17^{g}	196.2^{k}	39.09^{h}
H22	20.53^{abcdef}	46.19^{abcde}	0.6981^{a}	0.36^{ab}	19.2^{g}	48.19^{d}	200.9^{i}	39.09^{h}
H23	17.43^{f}	49.34^{a}	0.6834^{a}	0.36^{ab}	9.64^{m}	52.21^{b}	232.5^{a}	39.86^{f}
H24	21.63^{abcdef}	43.87^{cdefg}	0.6538^{a}	0.35^{ab}	25.58^{b}	42.17^{g}	219.5^{b}	39.86^{f}
H25	22.89^{abc}	48.14^{ab}	0.65^{a}	0.34^{ab}	17.01^{i}	42.17^{g}	192.2^{lm}	42.55^{b}
H26	20.33^{abcdef}	38.69^{jklm}	0.66^{a}	0.34^{ab}	16.02^{j}	40.16^{h}	190.9^{m}	40.24^{e}
H27	19.92^{abcdef}	46.65^{abcd}	0.6206^{a}	0.32^{ab}	21.33^{e}	42.17^{g}	193.5^{l}	37.55^{j}
H28	18.89^{cdef}	37.49^{klm}	0.65^{a}	0.33^{ab}	19.2^{g}	48.19^{d}	206.2^{g}	41.4^{d}
H29	20.01^{abcdef}	42.82^{defghi}	0.63^{a}	0.32^{ab}	19.2^{g}	40.16^{h}	216.3^{c}	41.77^{c}
H30	22.29^{abcde}	43.99^{cdefg}	0.72^{a}	0.32^{ab}	29.83^{a}	48.19^{d}	208^{f}	36.01^{m}
Mean	**20.58**	**42.61**	**0.64**	**0.32**	**16.82**	**44.98**	**199.57**	**38.06**
SE±	**1.34**	**1.253**	**0.075**	**0.029**	**0.03**	**0.031**	**0.441**	**0.025**
%CV	**6.5**	**2.9**	**11.7**	**9.2**	**0.2**	**0.1**	**0.2**	**0.1**
P-value	**0.001**	**0.001**	**0.812**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**

Means with the same superscript letter(s) in the same column are not significantly different ($P \leq 0.05$) following separation by Tukey's Test.

Key: CP = Crude Protein (%), K = Potassium (%), Mg= Magnesium, Cu = Copper, Zn = Zinc, Fe = Iron, Vit = Vitam

Table 4: Nutritional content (quality) of cashew (nuts or fruits) hybrids in combined analysis

Hybrid	%CP	%Fat	%K	%Mg	Cu (ppm)	Fe (ppm)	Vit C (mg/100mL)	Zn (ppm)
H1	21.46^{abcd}	43.13^{cd}	0.66^{a}	0.22^{d}	18.76^{k}	49.89^{d}	207.2^{de}	39.92^{i}
H2	19.23^{efghi}	37.36^{kl}	0.56^{abcd}	0.24^{bcd}	16.88^{n}	46^{g}	203.8^{g}	38.44^{n}
H3	19.78^{defghi}	43.99^{bc}	0.54^{abcd}	0.26^{bcd}	16.39^{p}	40.07^{op}	186^{r}	37.98^{p}
H4	18.84^{fghij}	39.41^{ij}	0.57^{abcd}	0.24^{bcd}	17.86^{l}	38.12^{r}	189.3^{op}	34.96^{u}
H5	20.2^{bcdefghi}	40.84^{fghi}	0.56^{abcd}	0.25^{bcd}	14.1^{s}	32.12^{v}	197.4^{k}	34.28^{v}
H6	20.62^{abcdefgh}	41.45^{defgh}	0.63^{ab}	0.34^{a}	11.26^{w}	44.19^{j}	202.2^{h}	42.55^{c}
H7	16.63^{k}	42.95^{cde}	0.54^{abcd}	0.24^{bcd}	19^{j}	43.03^{l}	192.9^{n}	38.12^{o}
H8	18.74^{ghijk}	42.06^{cdef}	0.47^{cd}	0.23^{cd}	10.75^{x}	45.09^{i}	192.5^{n}	31.81^{y}
H9	19.87^{cdefghi}	41.02^{efghi}	0.54^{abcd}	0.25^{bcd}	7.46^{y}	41.98^{m}	205^{f}	31.56^{z}
H10	19.96^{bcdefghi}	46.76^{a}	0.53^{bcd}	0.27^{bc}	12.38^{t}	38.1^{r}	200.3^{i}	33.48^{x}
H11	18.51^{hijk}	39.96^{ghij}	0.55^{abcd}	0.26^{bcd}	15.64^{q}	50.89^{b}	186.1^{r}	41.42^{e}
H12	21.66^{abcd}	36.32^{lmn}	0.55^{abcd}	0.28^{b}	20.16^{g}	50.75^{c}	196.7^{k}	43.73^{a}
H13	19.85^{cdefghi}	40.64^{fghi}	0.56^{abcd}	0.27^{bc}	12.38^{t}	40.11^{o}	206.8^{e}	37.5^{r}
H14	21.36^{abcde}	42.26^{cdef}	0.53^{abcd}	0.25^{bcd}	17.45^{m}	43.03^{l}	188.7^{pq}	39.26^{j}
H15	22.59^{a}	38.55^{jk}	0.53^{abcd}	0.27^{bc}	12.11^{u}	41.03^{n}	193^{n}	38.38^{n}
H16	22.09^{ab}	46.72^{a}	0.46^{d}	0.25^{bcd}	11.86^{v}	37.09^{s}	196.6^{k}	34.06^{w}
H17	20.73^{abcdefg}	35.07^{mn}	0.55^{abcd}	0.27^{bc}	27.66^{a}	52.9^{a}	204.7^{f}	40.23^{g}
H18	21.99^{abc}	40.04^{ghij}	0.55^{abcd}	0.28^{b}	19.09^{i}	46.96^{f}	208^{d}	38.78^{m}
H19	19.52^{defghi}	39.81^{hij}	0.61^{ab}	0.25^{bcd}	16.93^{n}	42.99^{l}	210.4^{c}	38.84^{l}
AC4	19.08^{fghij}	46.88^{a}	0.56^{abcd}	0.25^{bcd}	20.53^{f}	46^{g}	188.3^{q}	38.83^{lm}
H21	20.16^{bcdefghi}	41.29^{defghi}	0.52^{bcd}	0.28^{b}	15.66^{q}	39.06^{q}	189.9^{o}	35.31^{t}
H22	19.59^{defghi}	46.19^{a}	0.55^{abcd}	0.28^{b}	23.03^{d}	44.04^{k}	203.4^{g}	39.13^{k}
H23	16.63^{k}	41.85^{defg}	0.59^{abc}	0.29^{b}	15.38^{r}	48.01^{e}	216.8^{a}	38.8^{lm}
H24	19.09^{fghij}	45.34^{ab}	0.56^{abcd}	0.28^{b}	21.7^{e}	35.13^{u}	212.1^{b}	39.27^{j}
H25	20.42^{abcdefghi}	46.31^{a}	0.61^{ab}	0.35^{a}	17.83^{l}	45.18^{h}	194.4^{m}	42.16^{d}
H26	16.96^{jk}	34.39^{n}	0.53^{bcd}	0.28^{b}	16.51^{o}	36.09^{t}	195.3^{l}	40.66^{f}
H27	21.33^{abcde}	43.93^{bc}	0.58^{abcd}	0.27^{bc}	19.58^{h}	41.03^{n}	193.1^{n}	37.64^{q}
H28	18.41^{ijk}	34.88^{n}	0.58^{abcd}	0.27^{bcd}	18.93^{j}	44.04^{k}	195.3^{l}	43.15^{b}
H29	19^{fghij}	40.48^{fghij}	0.55^{abcd}	0.27^{bc}	25.49^{b}	40.02^{p}	212^{b}	39.99^{h}
H30	20.96^{abcdef}	36.86^{klm}	0.62^{ab}	0.27^{bc}	25.06^{c}	49.93^{d}	198.9^{j}	35.68^{s}
Mean	19.84	41.23	0.56	0.27	17.26	43.1	198.9	38.2
SE±	0.569	0.512	0.033	0.013	0.032	0.034	0.388	0.027
%CV	5	2.2	10.4	8.6	0.2	0.1	0.2	0.1
P-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Means with the same superscript letter(s) in the same column are not significantly different ($P \leq 0.05$) following separation by Tukey's Test.

Key: CP = Crude Protein (%), K = Potassium (%), Mg= Magnesium, Cu = Copper, Zn = Zinc, Fe = Iron, Vit = Vitamin

Table 5 shows the overall mean results of each nutritional attribute at each location and in combined sites. It was observed that cashew kernels at Nachingwea were richer in zinc and copper than those of Chambezi while on the other hand cashew kernels at Chambezi were richer in the rest of nutritional variables namely crude protein, fat, potassium, magnesium and iron contents

Table 5: Effects of location on nutritional variables in cashew in Southern and Eastern Tanzania

Location	%CP	%Fat	%K	%Mg	Cu (ppm)	Fe (ppm)	Zn (ppm)	Vit C (mg/100mL)
Nachingwea	19.1	39.84	0.48	0.22	17.7	41.21	38.33	198.25
Chambezi	20.58	42.61	0.64	0.32	16.82	44.98	38.06	199.57
Mean	19.84	41.225	0.56	0.27	17.26	43.095	38.195	198.91
SE±	0.147	0.132	0.009	0.003	0.005	0.005	0.004	0.058
P-value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Key: CP = Crude protein, K = Potassium, Mg = Magnesium, Fe = Iron, Zn = Zinc, Vit = vitamin

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Significant variations ($P \leq 0.05$) among hybrids were observed for quality parameters studied but there were no genotypic differences on calcium and sodium as no significance on Locations or Locations x Genotype interaction was observed. In this study, percentage protein content in genotypes ranged from 16.63 to 22.59% across the locations. This differed to some extent with results by Kapinga (2009) in Southern Tanzania, where the crude protein ranged between 16.2 to 18.7%, and also Ologunde et al. (2011) who reported protein in Nigerian cashew ranging from 23.42 –26.39%. Ohler (1979) reported 21% as average protein percentage in cashew nuts. Across the locations, hybrids H15, H16, H18, H12, H1, H14, H27 and H30 were identified as better hybrids in protein. On the other hand, Chambezi outperformed Nachingwea in protein probably due to more evaporation at Nachingwea that promotes volatilization (the loss of Nitrogen to the atmosphere as the component of amino acid) as the soil dries for a longer time at the later. Nachingwea experiences a prolonged period of months without rainfall. Also the soil moisture content might have caused this difference. Moisture should fill 15-70% of soil pore space (UH, 2007) for maximum mineralization (release of ammonia to the soil for plant uptake).

Overall fat mean of 41.23% obtained in this study was within the range of the results from Ologunde, et al. (2011) who reported percentage fat content of between 40.15 and 42.03%. Omosuli et al. (2009) recorded the percentage content of 43.95%. The genotypes and the environment are the possible reasons for the difference observed in fat content. The fat contents were higher at Chambezi compared to those at Nachingwea, probably for reasons provided by Mustafa et al. (2015) using canola crop. Mustafa et al. (2015) found that areas receiving higher precipitation give considerably higher oil and protein than the low rainfall areas.

Across the locations potassium content ranged from 0.46 to 0.66%, which conforms to the results recorded by Kapinga (2009) who reported potassium range of 0.44% to 0.77%. Chambezi had higher potassium content than Nachingwea probably this might have been caused by higher soil temperatures as warm temperatures quicken the release of potassium from K-bearing minerals. And so, mineral K and “fixed” K become available more quickly at higher temperatures (UH, 2007).

The magnesium content across the locations in genotypes ranged from 0.21 to 0.34%. The results agree with the study of Ologunde, et al. (2011) who obtained a range of between 0.20 and 0.39%. Low content of magnesium at Nachingwea might have been caused by the fact that magnesium availability is limited to soils that are acidic and Nachingwea had soil pH of 5.5. The higher magnesium content at Chambezi might have been due to inherent magnesium content in the soil. Magnesium becomes available when primary and secondary minerals containing magnesium dissolve or weather and rainfall is an agent of this process. After release magnesium is held by the cation exchange capacity and in the soil solution may precipitate into secondary minerals whereby it is taken up by plants (UH, 2007). Therefore, presence of more rainfall at Chambezi compared to Nachingwea might have speeded the release of magnesium ions and taken up by plants.

In this study, copper content in genotypes varied significantly across locations with the overall mean of 17.26 ppm which is a bit higher than the overall mean recorded by Kapinga (2009) which was 16.4 ppm. Copper content ranged from 4.7 ppm to 35.06 ppm with H17, H29, H30 and H22 appearing to be richer in copper content at both locations but also higher yielding hybrids. Therefore, selections of these hybrids have an added advantage of being good in copper. On the other hand, Nachingwea was better in copper, this may have been caused by the fact that copper availability decreases as pH increases, primarily due to decreased solubility of copper minerals (UH, 2007). Chambezi had higher soil pH than Nachingwea, which may have limited the availability of copper to plant roots leading to low content. Plants need copper so as to complete their life cycle-to produce viable seeds. Without copper there would be no photosynthesis because this nutrient is necessary for chlorophyll formation (Nutri-Facts, 2010).

Iron content for the hybrids ranged from 32.12 to 52.9 ppm across the locations. H17, H11, H12, H30, H1, H23 and H18 outperformed the control variety in combined analysis implying the possibility of having hybrids with higher iron content than the existing varieties. Chambezi was leading on this variable with the highest overall mean of iron (44.98 ppm) compared to 41.21 ppm recorded at Nachingwea. Possible reasons might be the interactions with other nutrients as excessive amounts of other micronutrients, particularly copper can decrease iron availability (UH, 2007). Nachingwea had higher amount of copper that might have interacted with iron and therefore reduced their availability to plant roots for uptake. Another reason might be the good soil aeration supported by the bimodal type of rainfall at Chambezi as this improves iron availability for plant uptake (UH, 2007). Iron is involved in photosynthesis, respiration, chlorophyll formation, and many enzymatic reactions.

Zinc content ranged from 31.56 to 43.73 ppm across the locations. So far, the zinc content recorded in this experiment outperformed the ones reported by Kapinga (2009), of 29.9 to 33.2 ppm but was within the range recorded by Ologunde et al. (2011) of 34.00 to 42.00 ppm. Nachingwea was better for zinc content probably due to the fact that zinc availability decreases as pH increases (UH, 2007). Nachingwea had less soil pH than Chambezi. Zinc is involved in growth hormone production and seed development.

The vitamin C content of the genotypes in this study ranged from 186.0 to 216.8 mg/100mL. The overall means at Chambezi and Nachingwea were generally lower (199.57 and 198.25 mg/100mL respectively) than those reported by Lowor and Agyente-Badu (2009) who reported vitamin C ranging between 206.2 to 268.6 mg/100mL. The genotypes and locations used could be the possible reason accounting for such difference. Vitamin C in plants functions in photosynthesis as an enzyme cofactor (including synthesis of ethylene, gibberellins and anthocyanins) and in control of cell growth (Smirnoff et al. 2000).

Table 6 shows relatedness of the various cashew nutritional quality attributes and especially with kernel yield. All significant correlations between nutritional attributes in the study and yield have been found to be negative. All positive correlations that existed with yield were not significant (P < 0.05). Nutrient contents that showed significant correlations with yield were Crude protein (r = - 0.188*), Potassium (r = - 0.355***), Magnesium (r = - 0.326***) and Iron (r = - 0.231).

From this study, it was observed that higher yielding genotypes are likely to have lower nutritional contents of Protein and minerals K+, Mg2+ and Iron. Contents of Fat, Vit C, Ca2+, Na+, Copper and Zinc seemed to be, however, not influenced by higher yield potential.

Table 6: Correlation of various nutritional attributes with yield and among the attributes in cashew

	%CP	%Fat	Vit_C	%K	Ca	Na	Mg+2	Cu	Zn	Fe	YIELD
%CP	1.000										
Fat	0.157	1.000									
Vit_C	-0.131	-0.012	1.000								
K	0.353**	0.228**	0.132	1.000							
Ca	0.024	0.180*	0.043	0.145	1.000						
Na	0.064	0.040	-0.182*	-0.012	0.005	1.000					
Mg^{+2}	0.207*	0.288**	0.135	0.731***	0.204*	-0.100	1.000				
Cu	-0.062	0.128	0.196*	0.249**	0.060	-0.136	0.237**	1.000			
Zn	-0.076	0.030	0.088	0.210**	0.152	-0.014	0.307***	0.505***	1.000		
Fe	0.167*	-0.066	0.092	0.415***	0.106	-0.116	0.366***	0.317***	0.393***	1.000	
YIELD	-0.188*	-0.120	0.121	-0.355***	-0.069	0.015	-0.326***	0.089	0.018	-0.231**	1.000

Number of observations: 177 ,Key: CP = Crude protein, K = Potassium, Ca = Calcium, Na = Sodium, Mg = Magnesium, Fe = Iron, Zn = Zinc, Vit = vitamin

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Relationship among the various nutritional attributes, on the other hand, was all the time positive whenever significant ($P < 0.05$), except between Na+ and Vit C. The correlation between Na and Vit C was significant but negative (r = - 0.182*). Other significant correlations among the nutritional attributes (+ve) existed between K+, Mg2+ and iron with CP; K+, Ca2+ and Mg2+ with Fat content; between Cu and Vit C content; K2+ and Mg2+, Cu, Zn and Iron; Ca2+ and Mg2+; Mg2+ and Cu, Zn and Iron; Cu and Zn and Iron and between Zn and Iron. Correlation between K+ and Mg2+ was record high and very highly significant (r = 0.731***). Other very highly significant correlations ($P < 0.001$) were those between CP and K; Fe and K; Mg and Zn; Mg and Iron; Cu and Zn; Cu and Iron; and between Zn and Iron. Correlation coefficients were according to Pearson and were based on 177 numbers of observations.

Very positive relationship between K+ and Mg2+ means each or one of the minerals has profound effect on uptake and accumulation of the other in the kernels. Interestingly, neither of the mineral elements nor the other mineral nutrients (Ca, Na, Cu, Zn, Fe) seemed to be critically limiting to kernel yield, since none showed significant positive relationship with yield. This may be perhaps related with the known Potassium enhancement of luxurious growth in plants when in excess. Results shown here have indicated very highly positive correlation between K and CP and perhaps this can be related with enhanced excessive vegetative growth at the expense of reproductive (kernel) growth. It is clear from the correlation relationship established that any high CP content detected in the kernels was unsupportive of and actually opposing high kernel yield. Since all the minerals K, Mg, Cu, Zn, Fe were having highly significant positive relationship with each other, there is possibility that they exerted collective effect on yield reduction especially through K, Mg and Fe. Effects of Cu and Zn on yield were far from significant.

Conclusion and recommendation

The nutritional quality characteristics of the hybrids showed variability. Hybrid H1 appeared to be suitable for a number of variables such as protein, fat, potassium, copper, iron, zinc and vitamin C. On the other hand, hybrids H2, H6, H17, H18 and H22 were the best in iron, zinc and vitamin C contents. Therefore, these hybrids are potentials for improvement or improved genotypes based on nutritional quality.

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