

# Challenges and opportunities toward sustainable consumption and value addition of cashew apples in Tanzania

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## Abstract

Cashew apple is an important healthy fruit due to its high nutrient contents, particularly vitamin C. However, its full potential is yet to be realized in low technological countries. This paper explores farmers' consumption habits, processing methods, and utilization constraints faced. Also, osmotic-solar dried product was developed. In an exploratory survey, 600 farmers across the surveyed districts were interviewed. The study revealed that the majority of farmers consume raw cashew apples, with 61.9% consuming more than five fruits a day and about 56.0% consuming almost every day during the season. About 43.7% of farmers traditionally process cashew apple porridge and alcohol. Lack of knowledge on post-harvest handling (86.2%), and processing technologies (82.7%) were mostly claimed to hamper the utilization. The developed dried products retained 59.4% of total acidity, 37.4% of total ascorbic acid, and 68.5% tannins. In addition, the product received better sensory scores and overall acceptability. Though solar drying relies heavily on weather conditions, where possible it could be a better alternative to traditional methods. The combination of blanching, osmotic dehydration and solar drying could provide economically feasible value added products to both urban and rural settings and ultimately reduce the post-harvest losses and unleash their economic potential.

## Keywords

Cashew apple, utilization constraints, post-harvest losses, solar drying, osmotic dehydration

## Introduction

Cashew (*Anacardium occidentale* L.) is a tropical evergreen plant native to the North and Northeast regions of Brazil (Zepka and Mercadante, 2009), bears cashew nut, the true fruit and cashew apple, the pseudo fruit. It is cultivated in 32 countries globally, with Brazil, India, Vietnam and Nigeria as the leading producing countries of cashew nuts. Cashew cultivation in Africa is geared toward nut production with less or no focus on the apples. Tanzania is among the highest cashew producers in East Africa region, and the main production areas are Mtwara and Lindi regions located in the south-eastern part of Tanzania, Coast region in the eastern part of Tanzania, and Ruvuma region in the southern part of Tanzania (Cashew Board of Tanzania, 2018). In addition, cashew is a potential cash crop in these regions. The production of cashew apple globally is 1.7 million tonnes, with Brazil (1,541,010 tonnes), Mali (92,856 tonnes), Madagascar (77,137 tonnes), and Guyana (5 tonnes) as the leading cashew apple producing countries (FAOSTAT, 2018).

Cashew apple is a hard, pear-shaped, non-climacteric, pseudo-fruit attached to the cashew tree on one side and the other side to the cashew nut, the true fruit. Cashew apple has been known to be a good source of vitamin C, polyphenols,

minerals, sugars, and some amino acids (Adou et al., 2012; Daramola, 2013; Msoka et al., 2017). Vitamin C content in cashew fruit is about four to six times that of tropical fruits such as orange and mango (Akinwale, 2000; Azoubel et al., 2005). Despite their nutritional and therapeutic benefits, they are normally regarded as waste products in cashew nut processing. However, this huge post-harvest loss is attributed to several factors including lack of proper post-harvest knowledge and skills, and the high perishability and astringency properties of the cashew apples (Akinwale et al., 2001; Nwosu et al., 2016).

Cashew apples are used to process a number of value added products such as juice, wine, jam, pickles, and ethanol (David and Prasad, 2015; Runjala and Kella, 2017). In Sub-

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Saharan Africa, processing of cashew apples into products such as juice (Akinwale, 2000; Gyedu-Akoto, 2011), jam (Gyedu-Akoto, 2011), wine (Ogunjobi and Ogunwolu, 2010), ethanol (Deenanath et al., 2015) and cashew fiber (Adegunwa et al., 2020) has been studied. Strangely enough, there are few studies on drying of cashew apples specifically, sun or solar drying (Falade et al., 2003). Sun or solar drying could be well exploited in this region due to long periods of sun's energy and cost-effectiveness in term of energy, labor, and instrumentation.

In Tanzania, much attention has been placed on cashew nut and many cashew farmers have benefited significantly in recent years due to market availability and most importantly, the increase in pricing value practiced by the government. Unlike cashew nut, the apples are not common or not even known to the people in the regions where cashew is not grown. In addition, there is little scientific information on their potential for food and nutritional security in the country. A report by Msoka et al. (2017) investigated the physical-chemical aspect of five cashew apple varieties. In this report, commonly grown varieties were shown to contain significant amounts of nutrients. Further to this, it is equally important to document constraints and utilization trends of cashew apple in order to build more insight on factors affecting their utilization. Therefore, in the present study, the exploratory survey (Study I) aims at documenting consumption, processing technologies, and constraints that hinder efficient utilization of cashew apples in Tanzania. The second objective (Study II) aims at developing a value added product using a combination of osmotic dehydration and solar drying as an attempt to reduce their massive loss.

## Materials and methods

### Study I: Exploratory survey

The study was conducted in Tandahimba (10°45' S, 39°38' E and Masasi rural (11°00' S, 39°15' E) districts of Mtwara region, Nachingwea (10°19' S, 38°48' E) and Lindi rural (10°31' S, 39°36' E) districts of Lindi region in 2019. The regions are located in the south-eastern part of Tanzania along the Indian Ocean. The regions and their corresponding districts were purposively selected because they are the leading cashew producers for cashew nut in the country (Cashew Board of Tanzania, 2018), and it is a potential cash crop for the people living in these regions.

A cross-sectional design was adopted in this study. It allows data to be collected at a single point in time and can be used for a descriptive study as well as for determination of the relationship between variables (Babbie, 1999). The sampling units were individual cashew farming households and processors from the study locations. A total of 600 registered cashew farmers were evaluated namely: 117 from Tandahimba, 159 from Masasi rural, 124 from Lindi rural, and 200 from Nachingwea districts. Cashew farmers were randomly selected to participate in the study on probability proportional to size basis. The size was based on the total number of registered cashew farmers in respective villages. From

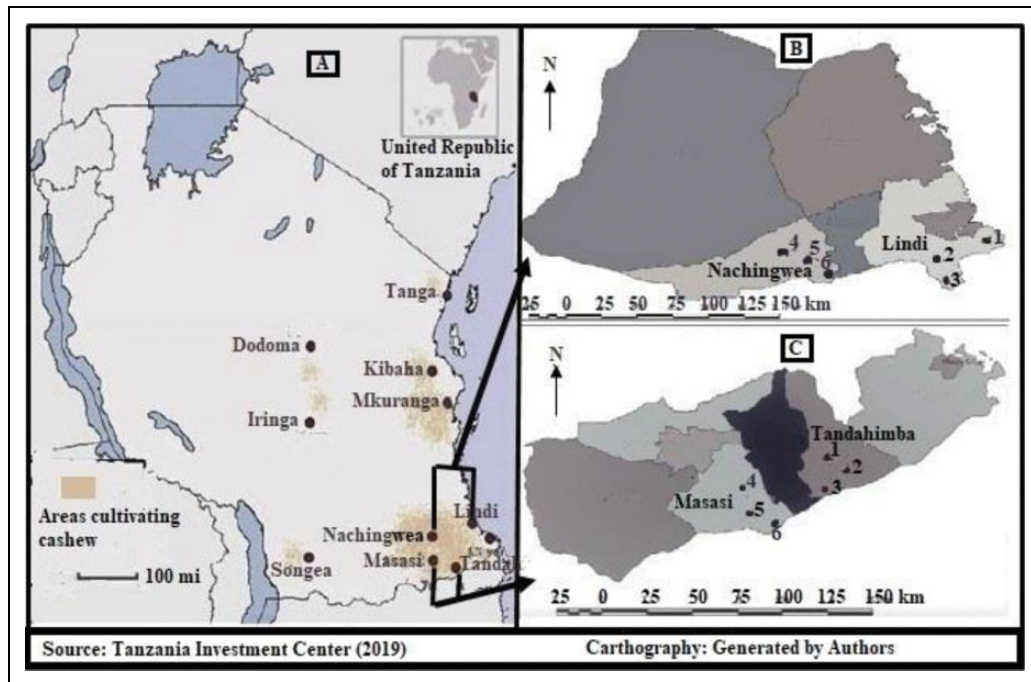
each district, three wards were purposively selected based on their cashew production potential followed by a random selection of two villages from each ward. The villages in their respective wards were Mkachima and Mapili (Chipolopola), Makong'onda and Mkwaya (Makong'onda), Mnavira and Manyuli (Mnavira), Miule and Mnaida (Nanhyanga), Namikupa and Chinati (Namikupa), Mnalani and Shangani (Mchichira), Mitumbati B and Mwenge (Mitumbati), Nambambo and Nampemba (Nambambo), Nangowe and Matangini (Nangowe), Nachunyu and Mmumbu (Nachunyu), Chiuta and Mikongi (Mandwanga), Nahukahuka B and Linoha (Nahukahuka).

Primary data were collected from the individual cashew farmers, processors, and key informants such as Agricultural Extension Officers. A semi-structured questionnaire was employed to obtain general information on cashew production, consumption habits of cashew apples, availability of processing technology, and constraints related to cashew apple utilization. Focus Group Discussion (FGD) and Key Informant Interviews were conducted to validate the information given by individual farmers. Participants who took part in the FGD included the cashew nut processors, Agricultural Extension Officers, District Agricultural Irrigation and Cooperatives Officers (DAICO), Research Officers and Ward Executive Officers (WEO). Audio recordings and notes-taking were used to gather information during the discussions. Secondary data were obtained from online resources such as the Cashew Board of Tanzania (Cashew Board of Tanzania, 2018).

### Study II: Value addition of cashew apples

The main objective of this study was to attempt product development from cashew apples by using osmotic dehydration and solar drying method in order to obtain a nutritious product with acceptable sensory attributes.

**Processing of dried cashew apples.** Red Brazilian Dwarf cashew apples were obtained from the orchards owned by the Tanzania Agricultural Research Institute—Naliendele (TARI) at Nachingwea district (10°19' S, 38°46' E; 442 meter above sea level). This variety of cashew apples and site were chosen because of low tannin contents, and high nutrients particularly sugar and vitamin C (Msoka et al., 2017). The fruits were washed with cold water, and blanched in hot water at 90°C for 5 minutes to reduce astringency. Then, they were transversely sliced (~10 mm) and dipped in 70% sucrose solution for 24 hours. Thereafter, the fruit slices were removed from the osmotic solution, drained, washed, and blotted in tissue paper to remove surface moisture, and weighed. Further drying was performed by using a natural convection mixed solar drier for 5 ± 1 days. During solar drying, the average temperature inside the drier was 50 ± 3°C. After sun set, the products were removed from the drier to avoid regaining of moisture from the surrounding. When the intended percent moisture (< 15% on dry basis) was attained, the products were removed and packed in low density polyethylene bags and stored at room temperature for further analysis.



**Figure 1.** Tanzania map showing areas cultivating cashew (A) and study sites (wards): Nachunyu (1), Nahukahuka (2), Mandwanga (3), Mitumbati (4), Nangowe (5), Nambambo (6) in Lindi region (B), and Nanhyanga (1), Namikupa (2), Mchichira (3), Makong'onda (4), Mnavira (5), Chipolopola (6) in Mtwara region (C).

*Physiochemical analysis of fresh and osmo-solar dried cashew apples.* Moisture content, pH, and total acidity of samples were determined as described by Bidaisee and Badrie (2001) with some modifications. Briefly, moisture content (g/100 g on dry basis) was obtained by drying the samples for 24 hours in an oven at 100°C. The pH of the sample was determined by homogenizing 20 g of well pulped sample in 100 mL distilled water and allowed to stand for 30 minutes. Filtrate was collected and centrifuged (Eppendorf Centrifuge 5810, Germany) at 3000 rpm for 10 minutes. The pH of the supernatant was measured on a digital pH meter (GHM 3531, Germany). The total acidity (% citric acid) of the sample extract (as prepared for pH) was determined by placing 25 mL of extract in a beaker and titrated against 0.1 N NaOH solution until the end point at pH 8.2 (Sadler and Murphy, 2010).

Total ascorbic acid content was determined as described by Kapur et al. (2012). Briefly, 5 g of sample was mixed with 25 mL of 3% metaphosphoric acid—8% acetic acid solution, and centrifuged at 4000 rpm for 15 minutes. Four milliliters (4 mL) of the extract was treated with 0.23 mL of bromine water (3%), followed by 0.13 mL of 10% thiourea solution, 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, cooled for 30 minutes and then treated with 6 mL chilled 85% sulphuric acid. Absorbance of the resulted red colored solution was measured spectrophotometrically at 521 nm. The total ascorbic acid content was estimated based on the standard curve of ascorbic acid and result was expressed as mg/100 g (dry basis).

Sample extract for total phenolic content (TPC) and tannin content determination was prepared as described by Ojha et al. (2017). Briefly, 10 g of pulped sample was mixed

with 30 mL methanol (80%) and centrifuged at 3000 rpm for 15 minutes. The extraction was repeated twice. 1 mL of the methanolic extract was diluted to 10 mL with methanol. TPC was determined using Folin-Ciocalteu method (Singleton and Rossi, 1965) as described by Mahdavi et al. (2011). Briefly, 0.5 mL of the diluted extract was mixed with 2.4 mL of distilled water, 2 mL of sodium carbonate solution (2%), and 0.1 mL of Folin-Ciocalteu reagent. The mixture was incubated in dark place at room temperature for 60 minutes. Absorbance of the sample was measured at 750 nm. TPC was calculated based on the standard curve of Gallic acid and expressed as mg/100 g (dry basis) of Gallic acid equivalent (GAE). To determine non-tannin phenolic content, 2 mL of the diluted sample was mixed with 100 mg polyvinyl-pyrrolidone (PVPP). The mixture was shaken, left for 15 minutes at 4°C and centrifuged at 3000 rpm for 10 minutes. Non-tannin phenolic content in the supernatant was determined in the way similar to the total phenolic content. Tannins content was estimated as the difference between total phenolic and non-tannin phenolic content in the dried samples.

*Sensory analysis of osmo-solar dried cashew apples.* The sensory characteristics of the dried products were evaluated using a 5-point hedonic scale. Sensory attributes such as color, taste, texture, astringent, aroma, and overall acceptability of two formulations were ranked by 100 untrained panelists from Masasi rural district. In addition, each panelist evaluated both products. The scale except for astringency was ranged from 1 'dislike very much' to 5 'like very much', and that for astringency were ranged from 5 'no astringent' to 1 'extremely astringent' (Bidaisee and Badrie,

**Table 1.** Socio-demographic characteristics of the participants, their cashew nut yields.

Variable	District				Mean (SD)	Chi Square
	Tandahimba	Masasi Rural	Lindi Rural	Nachingwea		
Gender (%)	Male	60.7	56.0	47.6	54.5	$\chi^2 = 4.33$ ; df = 3; $p = 0.23$
	Female	39.3	44.0	52.4	45.5	
Education level (%)	None	12.0	13.2	10.5	8.5	$\chi^2 = 18.88$ ; df = 12; $p = 0.09$
	Primary	78.6	79.2	87.1	83.0	
	Secondary	6.0	3.8	2.4	8.0	
	College	3.4	3.7	0.0	0.5	
Age (%)	18–29	6.8	9.4	8.9	7.0	$\chi^2 = 22.22$ ; df = 12; $p = 0.04$
	30–39	29.9	31.4	26.6	20.5	
	40–49	23.1	24.5	33.9	32.5	
	50–59	21.4	20.1	24.2	19.0	
	> 59	18.8	14.5	6.5	21.0	
Age (Years)	Mean (SD)	45.99 (12.92)	44.21 (11.85)	44.70 (10.30)	48.28 (14.03)	46.0 (12.6)
Household size (%)	1	0.9	1.9	0.0	5.0	$\chi^2 = 43.35$ ; df = 6; $p = 0.001$
	2–5	74.4	76.7	93.5	88.5	
	> 5	24.8	21.4	6.5	6.5	
Household size	Mean (SD)	4.64 (1.63)	4.41 (1.58)	3.64 (1.09)	3.58 (1.35)	4.0 (1.5)
Years in cashew farming (%)	1–5	13.7	12.6	13.7	16.0	$\chi^2 = 17.86$ ; df = 6; $p = 0.01$
	6–10	23.1	22.6	29.8	11.5	
	> 10	63.2	64.8	56.5	72.5	
Cashew farm per household (%)	0.5–5.0	61.5	44.0	61.3	68.5	$\chi^2 = 73.43$ ; df = 9; $p = 0.001$
	5.5–10.0	17.1	18.9	29.0	20.0	
	10.5–15.0	0.9	18.2	6.5	3.5	
	> 15.5	20.5	18.9	3.2	8.0	
Cashew farm per household (ha)	Mean (SD)	22.83 (54.29)	11.26 (14.32)	5.78 (4.10)	6.10 (7.81)	10.6 (26.2)
Yields in Kg (%)	< 200	7.7	6.9	0.0	6.0	$\chi^2 = 26.93$ ; df = 12; $p = 0.01$
	200–400	14.5	10.1	3.2	7.0	
	401–600	17.9	17.0	17.7	12.5	
	> 600	59.8	66.0	79.0	74.0	

2001). The formulations were osmotic solar dried product, and non-osmotic hot air oven dried product.

**Statistical analysis.** For study I, the information were collected using ODK (Open Data Kit) software, coded, organized, and uploaded to the Statistical Package for Social Science (SPSS) version 20.0. Data were analyzed and presented using descriptive statistics (mean, standard deviation, and percentages). The percentages were obtained for each group with similar responses in multiple answered questions. Comparative analysis was performed by using Chi square test at  $p < 0.05$  to evaluate the differences regarding farmers' consumption patterns, knowledge on the importance of cashew apples, processing of cashew apples, post-harvest constraints and socio-demographic characteristics.

For study II, normally distributed physicochemical measurements (mean  $\pm$  standard error of the mean) were done in triplicate and mean differences were compared by using t-test method. On the other hand, non-normally distributed sensory scores between osmotic solar dried and non-osmotic hot air oven dried products were analyzed by using Wilcoxon signed-ranks test at the significance level,  $p < 0.05$  under the *null hypothesis* that scores have the same distribution for both dried products and *alternative hypothesis* that scores are systematically higher for osmotic solar dried product.

## Results

### Study I

**Socio-demographic characteristics of participants.** The study surveyed 600 cashew farmers in the four districts, out of which 54.7% were male (Table 1). Most of the farmers (28.5%) fell to age group of 40 to 49 years. The average age of the farmers significantly varied ( $p = 0.04$ ) across the four districts, with the overall mean age of 46.02 years (Table 1). The highest level of education attained by the majority of farmers was primary education (82.0%) ( $\chi^2 = 18.88$ ; df = 12;  $p = 0.09$ ). About 83.3% of the participants had between 2 to 5 individuals in their household. In addition, the average number of individual did vary ( $p = 0.001$ ) across the surveyed districts with the average of four individuals per household (Table 1). The majority of the participants in all districts owned less than 5 ha (58.9%) ( $\chi^2 = 73.43$ ; df = 9;  $p = 0.001$ ), and having a cashew farming experience of more than 10 years (64.3%) ( $\chi^2 = 17.86$ ; df = 6;  $p = 0.01$ ). Furthermore, cashew nut yields varied significantly ( $p = 0.01$ ) across the districts, with 69.7% of farmers obtained more than 600 Kg per season (Table 1).

**Farmers' consumption habits of raw cashew apples.** On average, 97.7% ( $\chi^2 = 4.29$ ; df = 3;  $p = 0.23$ ) of farmers across the surveyed districts were reported to consume raw cashew

**Table 2.** Farmers' consumption habits of raw cashew apples across the surveyed districts.

Variables		Districts				Mean (SD)	Chi Square
		Tandahimba	Masasi Rural	Lindi Rural	Nachingwea		
Raw consumption (%)	Yes	95.7	99.4	97.6	98.0	97.7 (1.5)	$\chi^2 = 4.29$ ; df = 3; $p = 0.23$
	No	4.3	0.6	2.4	2.0	2.3 (1.5)	
Place (%)	Home	0.0	0.6	0.8	0.0	0.4 (0.4)	$\chi^2 = 126.56$ ; df = 6; $p = 0.001$
	Farm	61.9	42.4	87.7	26.5	54.6 (26.4)	
	Both	38.1	57.0	11.5	73.5	45.0 (26.6)	
Number of fruits per day (%)	1–5	60.2	37.3	21.3	33.7	38.1 (16.2)	$\chi^2 = 81.62$ ; df = 9; $p = 0.001$
	6–10	26.5	23.4	52.5	41.3	35.9 (13.5)	
	11–15	6.2	19.0	14.8	3.6	10.9 (7.2)	
	> 15	7.1	20.3	11.5	21.4	15.1 (6.9)	
Frequency per week (%)	1 day	15.0	6.3	0.0	6.6	7.0 (6.2)	$\chi^2 = 215.81$ ; df = 12; $p = 0.001$
	2 days	11.5	3.2	0.0	11.7	6.6 (5.9)	
	3 days	11.5	8.9	4.1	14.8	9.8 (4.5)	
	3 to 5 days	37.2	41.1	1.6	2.6	20.6 (21.5)	
	6 to 7 days	24.8	40.5	94.3	64.3	56.0 (30.3)	

**Table 3.** Processing of cashew apples by some demographic characteristics.

Variable		Processing of cashew apples		Chi Square
		Process	Not process	
Districts (%)	Tandahimba	15.4	84.6	$\chi^2 = 146.34$ ; df = 3; $p = 0.001$
	Masasi Rural	22.0	78.0	
	Lindi Rural	77.4	22.6	
	Nachingwea	60.0	40.0	
	Mean (SD)	43.7 (29.9)	56.3 (29.9)	
Gender (%)	Male	41.5	58.5	$\chi^2 = 3.32$ ; df = 1; $p = 0.07$
	Female	48.9	51.1	
	Mean (SD)	45.2 (5.2)	54.8 (5.2)	
Age (%)	18–29	39.6	60.4	$\chi^2 = 7.90$ ; df = 4; $p = 0.10$
	30–39	38.4	61.6	
	40–49	52.0	48.0	
	50–59	48.0	52.0	
	> 59	41.1	58.9	
	Mean (SD)	43.8 (5.9)	56.2 (5.9)	
Household size (%)	1	35.7	64.3	$\chi^2 = 14.59$ ; df = 2; $p = 0.001$
	2–5	48.2	51.8	
	> 5	26.2	73.8	
	Mean (SD)	36.7 (11.0)	63.3 (11.0)	
Years in cashew farming (%)	1–5	41.2	58.8	$\chi^2 = 0.69$ ; df = 2; $p = 0.71$
	6–10	43.9	56.1	
	> 10	45.9	54.1	
	Mean (SD)	43.7 (2.4)	56.3 (2.4)	

apples, out of which about 54.6% ( $\chi^2 = 126.56$ ; df = 6;  $p = 0.001$ ) consume only on farm during farming activities to quench thirst and hunger (Table 2). Of those who consume cashew apple fruits, about 38.1% ( $\chi^2 = 81.62$ ; df = 9;  $p = 0.001$ ) reported to consume between 1 to 5 fruits a day while other respondents could consume more than 15 fruits a day. Furthermore, 56.0% ( $\chi^2 = 215.81$ ; df = 12;  $p = 0.001$ ) of the consumers consume cashew fruits almost every day during the season (Table 2).

Regarding the knowledge on the importance of cashew apples, 52.7% ( $\chi^2 = 75.19$ ; df = 3;  $p = 0.001$ ) of the consumers reported to mainly consume cashew apples simply because they are fruits. Other reasons such as sweetness (25.8%) ( $\chi^2 = 7.25$ ; df = 3;  $p = 0.06$ ), good for health

(23.2%) ( $\chi^2 = 69.20$ ; df = 3;  $p = 0.001$ ), quench thirst and hunger (9.7%) ( $\chi^2 = 20.77$ ; df = 3;  $p = 0.001$ ), and due to appetite (0.8%) ( $\chi^2 = 4.31$ ; df = 3;  $p = 0.23$ ) were also pointed out. On the other hand, a small proportion of those who do not consume these fruits claimed this was due to astringency, health problems, feeling of dislike, and fear of pesticides used during cashew production.

**Processing of cashew apples.** In this survey, the majority of the farmers (56.3%) across the surveyed districts did not process cashew apples (Table 3). Based on the analysis it shows that processing of cashew apples significantly depended on the farmers' location ( $\chi^2 = 146.34$ , df = 3,  $p = 0.001$ ), and household size ( $\chi^2 = 14.59$ , df = 2,  $p = 0.001$ ), but it did

not significantly depend on farmers' gender ( $\chi^2 = 3.32$ ,  $df = 1$ ,  $p = 0.07$ ), age ( $\chi^2 = 7.90$ ,  $df = 4$ ,  $p = 0.10$ ), and cashew farming experience ( $\chi^2 = 0.69$ ,  $df = 2$ ,  $p = 0.71$ ). Moreover, among the processing methods applied in the study areas, cooking of cashew apples into porridge locally known as *Mkongohu* was mentioned by 64.7% of the farmers, followed by alcohol fermentation (30.6%), sun drying (21.2%), and juice processing by the smallest proportion (1.5%) of farmers (Table 4).

**Post-harvest constraints faced by farmers regarding the utilization of cashew apples.** Among the constraints that hinder efficient utilization of cashew apples, the lack of knowledge on post-harvest handling was mentioned by 86.2% ( $\chi^2 = 58.19$ ;  $df = 3$ ;  $p = 0.001$ ) of farmers, followed by the lack of quality processing technology (82.7%) ( $\chi^2 = 60.58$ ;  $df = 3$ ;  $p = 0.001$ ), and absence of reliable market (39.8%) ( $\chi^2 = 13.07$ ;  $df = 3$ ;  $p = 0.004$ ). Other constraints included the low price of the produce (10.5%) ( $\chi^2 = 21.20$ ;  $df = 3$ ;  $p = 0.001$ ), lack of electrical energy (4.5%) ( $\chi^2 = 35.58$ ;  $df = 3$ ;  $p = 0.001$ ), and the astringent property of the fruit (0.7%) ( $\chi^2 = 16.62$ ;  $df = 3$ ;  $p = 0.001$ ). Therefore a large proportion of cashew apples are left to rot in the field, and some are used for feeding animals such as cows, sheep and goats.

**Table 4.** Processing methods employed by farmers in study areas.

Method	Products	Percentage (%)
Cooking	Porridge ( <i>Mkongohu</i> )	64.7
Alcohol fermentation	Fermented drink ( <i>Uraka</i> ) and distilled ( <i>Nipa</i> )	30.6
Sun drying	Dried cashew apples ( <i>Kochoko</i> )	21.2
Juice processing	Juice	1.5

**Table 5.** Physicochemical properties of fresh and solar dried fruits.

Variable	Fresh fruit	Solar dried fruit
Moisture (%)	81.3 ± 0.2	13.8 ± 0.3
pH	3.80 ± 0.01 <sup>1</sup>	4.55 ± 0.03 <sup>2</sup>
Total acidity (% citric acid)	0.32 ± 0.01 <sup>1</sup>	0.19 ± 0.01 <sup>2</sup>
Tannins (mg/100 g Gallic acid equivalent)	388.96 ± 7.37 <sup>1</sup>	266.59 ± 1.89 <sup>2</sup>
Total ascorbic acid (g/100 g)	1.95 ± 0.09 <sup>1</sup>	0.73 ± 0.01 <sup>2</sup>

Means with similar superscript in the same row are not significant different ( $p > 0.05$ ).

**Table 6.** Sensory scores of formulated dried products ( $n = 100$ ).

Data	Sensory attribute	Mean Rank (Positive)	Sum of Ranks (Positive)	Z value	Exact p value (2-tailed)
OsmoSolar-NonOsmoOven	Color	48.50	4656.00	-8.84	0.001
	Texture	49.00	4753.00	-9.06	0.001
	Taste	50.50	5050.00	-9.29	0.001
	Aroma	50.00	4950.00	-8.98	0.001
	Astringency	50.50	5050.00	-8.98	0.001
	Overall acceptability	50.50	5050.00	-9.07	0.001

## Study II

**Physicochemical properties of fresh and solar dried fruits.** Moisture content of the dried samples was maintained below 15% on a dry weight basis, which is within the maximum permissible moisture content (20% dry basis) for osmotic dehydrated fruits (Table 5). The dried fruit product had significantly ( $p < 0.05$ ) lower total acidity and higher pH than fresh fruit. Similarly, the total ascorbic acid and tannin contents were significantly lower in solar dried samples than in fresh fruit samples.

**Sensory evaluation of solar dried fruits.** The sensory attributes of formulated products were assessed in order to understand the acceptability of consumers before launch into the market. The mean ranks, sum of ranks, Z values, and exact  $p$  values for sensory attributes of the dried products are presented in Table 6. According to the results obtained from Wilcoxon signed-ranks test, osmotic solar dried products had significantly higher scores at 5% levels with regard to color ( $p = 0.001$ ), texture ( $p = 0.001$ ), taste ( $p = 0.001$ ), aroma ( $p = 0.001$ ), astringency ( $p = 0.001$ ), and overall acceptability ( $p = 0.001$ ) and thus mostly preferred by the panelists than non-osmotic hot air oven dried products. Furthermore, the texture of non-osmotic hot air oven dried products was indicated by panelists to be too tough than osmotic solar dried products.

## Discussion

The finding from this study shows a fair participation of both genders (45.3% female, 54.7% male), which is important to capture points of view from both sides. It is noteworthy that, the contribution of women in agriculture and the cashew industry in particular is well recognized (Njuki et al., 2013). The results also show that in traditional processing of cashew apples both genders play a significant role ( $\chi^2 = 3.32$ ;  $df = 1$ ;  $p = 0.07$ ) (Table 3). This could be due to the fact that, both genders considered cashew crop farming as their main source of income and perhaps for food, considering about 83.3% of households host between 2 to 5 individuals (Table 1).

The majority of cashew farmers across the surveyed districts belonged in middle age category (Table 1), though due to the importance of cashew farming as a cash crop in the area, the contribution of youth and elders cannot be ignored. This is attributed to the fact that, the government raised the price of cashew nuts from 2,000 to about 3,500 TZS (0.86–1.51 USD) per Kg in the 2018/2019 season, with the

government being the primary market of cashew nuts. A good merchandizing price may encourage more individuals especially the younger generation to engage in cashew farming. According to Segre et al. (2014), the availability of a reliable market influences the higher production of crops, and hence greater participation of people in farming. Furthermore, processing of cashew apples was observed to be performed with the majority of middle-aged individuals, and with farming experience of more than 10 years (Table 3). This could be due to the knowledge they gained over the years through media, extension officers, or word of mouth about possibilities for cashew apple processing and eventually the benefits from cashew apples. Moreover, though cashew apples were traditionally processed, some products such as fermented juice “*uraka*,” distilled alcohol “*nipa*” production and preservation of dried cashew apples “*kochoko*” require expertise and experience, thus these products are produced by fewer processors.

In this survey, nearly all cashew farmers consume fresh cashew apples. The study also found that, about 54.6% of consumers preferred to consume cashew fruits while they are at their farms only, with only 0.4% of consumers consuming at home. This could be due to the lack of knowledge on post-harvest handling as well as lack of electricity in some areas which is necessary for modern cold storage to increase the shelf life of the fruits. This provides minor reason (s) such as the inconvenience of carrying the fruits all the way back home. About half (45.0%) of consumers consume both at home and farm, and this could be due to the fact that, in some areas cashew farms are near to the residential houses, thus consumption at both places seems to be possible regardless of the lack of preservation technologies. In addition, a handful of fruits could be brought home not only for raw consumption but also for the preparation of products such as porridge “*mkongohu*” and an alcoholic drink “*uraka*.”

Although the consumption of raw fresh cashew apples is considerably high, the reasons for consuming the fruits clearly reflects the lack of knowledge on the importance of cashew fruits. For instance, the most claimed reason for cashew fruits consumption (52.7%) was because they are fruits, even though some responses show that consumers are aware of the contribution of fruits to human health. From the scientific point of view, the functional properties such as antioxidant and anti-inflammatory activities are responsible for the ability of cashew apple to promote or treat a number of chronic diseases such as scurvy, cancer and neurodegenerative diseases (Runjala and Kella, 2017). Therefore, training on the importance of cashew apple particularly at village level is necessary to increase awareness of the vital health benefit of cashew apples to human health and also to promote postharvest handling, value addition and market demand.

It is noted from this study that despite the high consumption of raw cashew apple by the majority, the processing of cashew apples is done by the minority due to the lack of processing skills and quality post-harvest technology, among others. Cashew apple porridge “*Mkongohu*” is the major traditional processed product due to the fact that it is easy to prepare, cost-effective, sweet and non-alcoholic

(Table 4). Unlike *Mkongohu*, the fermented “*Uraka*” and distilled “*Nipa*” beverages are preferred mainly as the source of income. For instance, *Uraka* normally sold at a price of 500 TZS per liter, while only 200 ml of *Nipa* is sold at 500–1,000 TZS. *Nipa* is prepared by soaking sun-dried cashew apples in water for about 1 week and thereafter simple distillation of the filtered liquid. Unlike *Uraka*, *Nipa* is processed throughout the year due to the fact that it uses dried apple fruits which could be stored for about a year. From the market perspective, *Nipa* is a good income generator for cashew farmers, but unfortunately the Government of Tanzania banned the production of local distilled alcohol due to their considerable high, unknown and unregulated alcohol contents.

Osmotic-dehydrated solar dried cashew apples could be a better alternative to traditional products. Despite the loss of nutrients encountered during blanching, osmotic dehydration, and drying, the process produced a nutritious product (Table 5) and with better sensory attributes (Table 6). The benefit of the osmotic dehydration process prior to drying is well documented (Yadav and Singh, 2014). It reduces drying time, retains much nutrients and organoleptic attributes, hence impart desirable characteristics to the finished products. Processing of fruits into dried products is a very feasible method both industrially and in local situations compared to other products such as juice, jam, and wine. Drying offers many advantages including the ease of preparation and storing, reduction of saving in packaging and energy, and products are of light-weight, hence convenient. It is noteworthy that, the issue is not just to dry the fruits but also to make sure that the resulting product is nutritious, convenient and highly acceptable to consumers. Solar drying is a cost-effective, user friendly, and sustainable drying method than other sophisticated drying methods.

The Tanzania Agricultural Research Institute-Naliendele and Ndanda Mision run by the Benedict Fathers are the only sites in Tanzania where cashew apples are processed into products such as juice, jam, and wine (UNIDO, 2011). However, the products have never reached the marketing stage due to various reasons such as limited investment. For instance, wine and juice processing requires large investment in terms of instrumentation and labor. On the contrary, drying technology offers products which are easy to prepare, store, use, and commercialize. Thus, osmo-solar drying could be similarly employed. Further to this, training of individuals, small and medium enterprises (SMEs), and womens groups on cashew apple processing could be a feasible approach to accelerate the exploitation of fruits. For example, TechnoServe through the BeninCaju project is collaborating with local entrepreneurs to process cashew apple into juice in Benin, hence improve nutrition and create employment particularly for women (TechnoServe, 2017). Above all, with the ongoing expansion of cashew plantations to non-coastal regions of the country taking pace (Cashew Board of Tanzania, 2020), active engagement of researchers, government, and other stakeholders is required to effectively utilize cashew apples.

Due to the perishability nature of cashew apples, challenges such as lack of knowledge on post-harvest handling

and processing technologies hinder the efficient utilization of cashew apples. The results are in agreement with that of Nwosu et al. (2016) who claimed the same constraints to limit utilization of cashew fruits in Nigeria. At present in Tanzania, there is no standardized and commercialized cashew apple products in the market. Similarly, in other cashew producing countries, as in West Africa (Ghana, Benin and Guinea-Bissau) there is little effort regarding cashew apple usage (Monteiro et al., 2017). It is reported that, no country in Africa is processing greater than 1% of its cashew apple production (Yantannou, 2017). From this perspective, a lesson can be learnt from Brazil where there are more than 12 juice factories processing cashew apples into products such as juices, soft drinks, cajuina, fresh fruits, jams, colorants, candies, and animal feeds. Equally important, the Brazilian Agricultural Promotion Agency (EMBRAPA) has developed a cashew apple variety that can remain on the ground for 1 day without being damaged or beginning to ferment. Therefore, there is a clear underutilization of cashew fruits which on the other hand creates market opportunities for value added products in the country and Africa as a whole.

## Conclusions

Cashew apples in the selected areas were found to be underutilized. The small utilized proportion is mostly consumed in the raw state, with the frequency and number of fruits consumed by an individual being high. In addition, processing of the fruits into value added products was found to be a major concern, with few cashew farmers claiming to traditionally process cashew apples and all processed products being seasonal except distilled alcohol which is processed throughout the year. This implies that, a large quantity of fruits are being wasted. Among others lack of knowledge on proper post-harvest handling, lack of quality processing technology, and lack of a reliable market are the major constraints which hinder the full utilization of cashew apples. Addressing these constraints would be a clear pathway toward the reduction of post-harvest losses. From the nutrition perspective, the rural dwellers benefit from the potential of cashew apples mostly through direct consumption of the fruit and processed products like *Mkongohu* and *Uraka*. However, this benefit disappears during the off-season due to the very short shelf life of the fruits and the two products. Value addition of cashew apples, for instance osmo-solar dried products could be developed even in a rural setting for food and as an income generator. This will enable a remarkable reduction of post-harvest losses encountered at present, and in general contribute to the growth of the national economy.

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