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Underutilized Cashew Apple Fruit: Its Utility and Development as a Source of Nutrients and Value Added Products in Tanzania

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Abstract

The tropical cashew tree, *Anacardium occidentale* L., has remarkable potential. The tree produces the pseudo-fruit known as the cashew apple and nuts. The apple is sweet, juicy, and loaded with dietary fiber, phytonutrients, minerals, and vitamin C. Despite having high nutritional content, the cashew apple is neglected in low-technological nations like Tanzania, primarily because of negligence over the well-known nut, its perishability, and its astringent taste. Contrarily, cashew apples are processed into various goods in high-income nations where food processing and technology improvements have been realized. Cashew apple products include juice, syrup, wine, alcohol, dietary fiber extracts, and animal feed. However, inadequate technologies and skills for postharvest handling and value addition have led to a considerable loss of cashew apples, contributing to pronounced food and nutrition insecurity. This review documents the production of cashew apples in Tanzania and reveals the fruit's critical underutilization and potential nutrition and economic opportunities. This documentation may call for interventions to create awareness of the importance of cashew apples in social-economic, food, nutrition and health, empower locals, and invite new processing technologies to diversify and extend shelf-life. The ultimate goal is to promote the utilization of this abandoned nutritious fruit. Such approaches may reduce postharvest losses and impact food and nutrition security and the social-economic empowerment of smallholder farmers.

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Introduction

Cashew (*Anacardium occidentale* L) is an evergreen nut-bearing tree that originated from Cerrados of Central Brazil.[1,2,3,4,5] The Portuguese discovered the tree in Brazil between the 16th and 17th centuries before its introduction to India, Mozambique, and East African countries, including Tanzania.[4]

As opposed to leaves, stems, barks, and roots, which are only thought to be necessary for the survival of the tree[6] and to provide shade and ground cover, cashew nuts and cashew apples are the two main products of interest from the cashew tree. The largest nut producer for 2014–2018 in India, with an annual average output of 745,000 tones, followed by Côte d'Ivoire, 675,000 tones, and Viet Nam, 296,000 tones, while Tanzania was in the fourth position with 220,000 tones.[7] In Tanzania, Mtwara, Lindi, and Ruvuma are the main producing regions contributing over 80% of the national cashew nut production.[8]

The weight of the fruit comprises 10% nuts and 90% apples, respectively.[9] Although the cashew apple weighs 9-fold more than the nut, the cashew nut has been considered the primary product from the tree and the driver underlying cashew tree cultivation in Tanzania and many other countries, with little or no attention to cashew apples.

Cashew apples are soft, juicy, slightly fibrous, astringent in taste, and covered with thin, waxy skin that easily bruises. They are mostly heart-shaped, 3-6 or more times larger than the nut, and when fully ripe, they are bright red, yellow, or a mixture of the two colours. The fruit has about six times more vitamin C per 100ml than orange juice, with an average vitamin C content of 200–269 mg/100ml.[10,11,12] also contains anti-oxidants, sugar, amino acids, and phenolic compound.[10,13,14] At the same time, there is an increase in cashew nut production and utilization worldwide and huge postharvest loss of its apple persists.[15,16] For example, in Nigeria, Kogi State has reported a loss of about 467 kg of cashew apple per hectare.[17] Similarly, Tanzania has reported approximately cashew apple production of 3,138,260.4 tones in season 2017/2018,[16] of which the majority was left to rot in the farms. Globally, the loss of cashew apples is about 95 %, approximated from global production of cashew apples of about 30 million tones per annum[18] Despite their nutritional value and massive production, cashew apples are considered as waste, hence a non-targeted fruit during cashew nut production in less technological countries, including Tanzania.

After the nuts are harvested, more than 80% of the apples are left to rot in the farms, and only a small proportion is consumed during the season as snacks to quench thirst and hunger during farming activities.[19, 20] Moreover, cashew apples are neither harvested for family consumption nor marketed locally or internationally as they are too perishable to transport in places with no cold chain.

Cashew apple utilization is mainly hampered by its high perishability leading to speedy deterioration and inadequate skills and technologies for processing and preservation to extend shelf life.[14] Additionally, astringent taste and negligence due to insufficient knowledge of their importance in food and nutrition security[21,22] have contributed to this critical lack of attention. Therefore, abandoning cashew apples in the farms leads to a massive loss of nutrient-dense food that could otherwise improve food/feed and nutrition security, and ultimately well-being and social-economic transformation; if consumed fresh, processed alone, or incorporated into other food products.

Consequently, including cashew apples in value-added products such as juice, jam, and wine will help decrease postharvest loss and could help Tanzania's economy and small-scale farmers' quality of life.

Additionally, processing cashew apples can generate employment possibilities in rural areas, notably for women and young people. This may benefit the nation's efforts to reduce poverty and foster sustainable economic growth To fully unleash the potential of cashew apples in Tanzania, addressing will be essential. This can be accomplished by investing in infrastructure, assisting small-scale farmers, and creating efficient distribution and marketing networks.

Therefore, it is imperative to gather comprehensive information on cashew apple production and reveal its critical underutilization and opportunities for smallholder farmers' food and nutrition security, trade, and social-economic transformation. This information can be used by agricultural extension

agents, food value-addition stakeholders, and governments to promote cashew apple utilization with value addition for shelf-life extension. It is an attempt to promote the utilization of this abandoned nutritious fruit, emphasizing the reduction of postharvest losses with an ultimate impact on food and nutrition security as well as socio-economic transformation.

Cashew Nut Production

The cashew tree is widely cultivated in the southern coastal regions of Tanzania, which includes Mtwara, Lindi, Ruvuma, and Pwani, and its nuts are the primary harvest and driver of cashew tree cultivation. As a result, the nuts are of high economic importance to the country, while the apples are of less significance but enjoyed as a by-the-way field snack during the harvesting of the nuts, or a small population of native brewers uses only a tiny proportion as raw material for a local brew. Moreover, the trees are enjoyed for their sun shed throughout the year.[23]

Tanzania, after Mozambique, was the second-largest producer of cashew nuts in the world, with a peak production of 145,000 metric tones in 1973–1974.[24] The nation produced almost 20% of the world market in those years. Since then, the production of cashew nuts has decreased, reaching a low of 16,500 metric tones in 1986 and 1987. Midway through the 1990s, output began to increase again, whereby in 2000, Tanzania recorded cashew nut production as high as 121,200 metric tones.[25]

Again, in the mid-2000s, Tanzania experienced a slight decline in cashew nut production which was recovered in 2011, and the country exported about 158,134 metric tones.[26] The highest cashew nut production was recorded in 2017/18 when over 313,826.4 tones were produced[8] Figure 1. Then the production declined in 2018/19 and 2019/20 by recording 225,305 and 232,681.8 metric tones, respectively.[27]

Despite various efforts for agro-industries development in Tanzania, the cashew sector has been a missed opportunity for many years. The cashew nut industry has been promising, although it has not yet attained the expected level of development.[28] This is because the Tanzanian cashew sector, like in the rest of Africa, is characterized by low productivity, market stability, and value addition. The sector is recorded to lose at least US$550 million in value addition alone.[28]

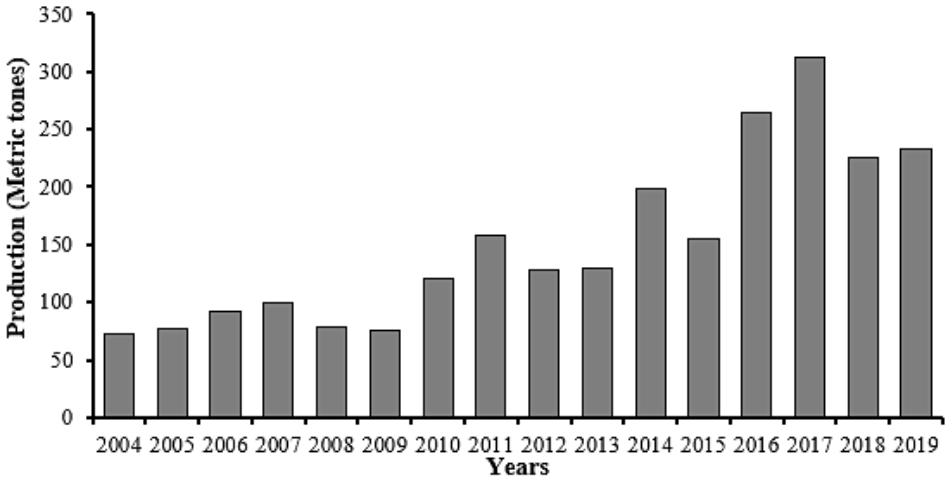

Fig. 1: Tanzania raw cashew nut production from 2004 to 2019[27]

Economic Importance of Cashew Nut

Tanzania's top four export crops are cashew nuts, cotton, coffee, and tobacco. Mtwara region produces 71% of the nation's output of raw cashew nuts, followed by the Lindi region (18%), Coastal region (8%), and other producing regions, including Ruvuma and Tanga, sharing the remaining 3%. About US$ 75 million was made by the sector in 2005, US$ 70 million in 2008-09, and US$ 140 million in 2010-2011.[29]

The government initiative to implement the Warehouse Receipt System (WRS) in the primary producing region of Mtwara, and afterwards in the Lindi, Coast, and Ruvuma regions, was deemed to have given the 2007–2008 season's revenues a boost.[29,30]

The term "Warehouse Receipts System" refers to a form of commerce where commodities are stored in a licensed warehouse or warehouses, and the owner of the commodity receives warehouse receipts outlining ownership, value, type, volume, and quality (grades) of the deposited commodities.[31] Tanzania Warehouse Receipts Act No. 10 of 2005 governs the issuance of warehouse receipts[32] which was amended in 2015.

The WRS facilitates a simple mechanism by which traders, producers, and lenders can secure a floor price by looking at a fixed future price. The system benefits the producers in developing countries as they mostly lack means of mitigating price risk, affecting their income and being unable to repay loans.[33] WRS provides smallholder farmers with consistent pricing and links them to resources, including extension assistance, mechanization, seeds, fertilizer, loans, and guarantees of profitable markets for their produce.[33,34] Moreover, WRS facilitated additional liquidity (bank financing) to the farmers in the sector through primary society and cooperative unions as they have access to independent banks.[35]

Nevertheless, in 2018 when the production tripled compared to the year 2007/8, which led to the formation of WRS, the government intervened by increasing the unit price of cashew nuts from TZS 2,000 to a minimum of TZS 3,500 per kilogram of nuts.[22] Enforcement of this selling price was successful as products were stored at the government warehouses for joint marketing. Moreover, since 80–85% of the output was exported in its raw form and only 15% was locally processed for domestic and international markets, this intervention had no significant impact on quality value addition.[36]

The current marketing challenges include price volatility for both raw cashew and kernels, low levels of processing to meet critical volumes and standards required in international markets, a small domestic market for kernels, low levels of product diversification, low levels of farmer knowledge of the WRS, a lack of a brand label for Tanzanian cashew, and high transaction costs that reduce producers' profits.[29] Consequently, despite the initiatives, cashew marketing problems persist. Therefore, to offer alternative policy and marketing guidance that will improve sustainable cashew nut marketing in Tanzania, more work must be done to understand the issues better.[36]

Cashew Apple (CA)

Aside from the cashew nut, which is the main product of the cashew tree, two more cashew by-products that are processed and consumed worldwide are cashew nut shell liquid (CNSL) and cashew apples[37] Despite the fact that cashew nuts are the cashew tree's primary commercial product, cashew apple yields are eight to ten times greater than the weight of raw nuts.[3,37,38] The pseudo and non-climacteric fruit CA grows from the pedicel and is linked to the nut. The ripe apple has delicate skin that can bruise easily, and it is extremely juicy, spongy, slightly fibrous, and aromatic.[21] In addition, the thin skin makes it more sensitive to physical harm, which speeds up deterioration. Therefore, careful handling is necessary, particularly while transporting raw fruits.

The fruit's morphotypes are commonly yellow or red, Figure 2. Nevertheless, Benin reported a yellow-orange morphotype.[39] The colour differences are mainly due to the loss of chlorophyll, which goes parallel with the gradual increase in carotenoid pigments and anthocyanins during the maturation of cashew apples.[40] Five cashew varieties with the names Anacardium Ceylon 4, Anacardium Ceylon 10, Brazilian dwarf, Anacardium Zanzibar 2, and Anacardium Zanzibar 17 have been reported from Tanzania[6]

a b

Fig. 2: Yellow (a) and Red (b) cashew apple varieties are attached to the tree on one end and to the nuts on the other[22, 41]

Cashew apple has received less attention in some countries, including Tanzania, where it is neglected and considered a by-product of cashew nut production. They are not preciously consumed or sold fresh and have not been processed as value-added products. The underutilization of cashew apples, which are either left to rot in the field after the nuts are harvested, or only a small portion of the total yield is used as fresh fruit in the field during the nuts' collection, or they are fermented to unregulated non-commercial local brew called "Uraka" in Swahili.[6]

Lack of information about its significance in ensuring food and nutrition security, inadequate postharvest handling, and a lack of value-adding technologies[6] to diversify its consumption patterns and extend shelf life for simple transit all contribute to its underutilization. In addition, the fruit is highly perishable and seasonal, limiting its utilization in places where the cold chain and shelf-life extension technologies have not been realized. During postharvest, cashew apples are subjected to stress such as physical damage, high temperatures, and lengthy storage that can speed up their perishability.[43] In order to prevent postharvest losses, careful handling is necessary, especially when transporting fresh fruits. For instance, CA has been carried approximately 3000 km in Brazil with lower postharvest losses than in other nations.[42]

Growth and Maturity of CA

The growth and maturity of cashew apples involve several stages, during which the nutritional content of the fruit undergoes significant changes. The cashew apple is an edible fruit that grows on the cashew tree, and it starts as a small, greenish-yellow fruit that gradually grows larger and more yellow or red as it matures. As the fruit develops, it accumulates sugars and other nutrients, resulting in taste, texture, and nutritional content changes.

In the early stages of growth, the cashew apple is high in vitamin C, beta-carotene, and other anti-oxidants. The sugar content increases as the fruit mature, becoming sweeter and less acidic. It also becomes a good source of dietary fiber, potassium, and other minerals at this stage.

When the cashew apple reaches full maturity, it develops a soft, pulpy texture and a rich, sweet flavor. At this point, it is at its nutritional peak, with high levels of dietary fiber, anti-oxidants, and minerals such as potassium, magnesium, and iron.

However, after reaching full maturity, the cashew apple starts to deteriorate rapidly and loses its nutritional value. Therefore, harvesting the fruit at the right time ensures maximum nutritional content.

Therefore, the growth and maturity of cashew apples involve significant changes in taste, texture, and nutritional content, with the fruit, becoming sweeter and more nutritious as it matures. However, to get the most out of this fruit's nutritional benefits, it is essential to harvest it at the right time.

Cashew Apple Edible Products

There are several edible products which can be made from cashew apples, including,Cashew apple juice. The juice can be made by blending the cashew apple pulp with water and sugar to taste.[2] Cashew apple jam, Cashew apple jam is a sweet spread

that can be made by cooking the cashew apple pulp with sugar and pectin.[18] Cashew apple chutney, Cashew apple chutney is a savory condiment that can be made by cooking the cashew apple pulp with spices, vinegar, and sugar.[18] Cashew apple wine. Cashew apple wine is a fermented beverage made by fermenting the cashew apple juice with yeast.[46]

Cashew apple vinegar: Cashew apple vinegar is a type of vinegar that is made by fermenting the cashew apple juice with acetic acid bacteria.[18] Dried cashew apple, The cashew apple can also be dried and used as a snack or added to recipes as a sweetener or flavoring agent.[56] Cashew apple tea, Cashew apple tea can be made by steeping dried cashew apple pieces in hot water.

Cashew Apple Non- Edible Products

Cosmetics: Cashew apple extracts are also used in cosmetics and skincare products. The antioxidants in the fruit can help to protect the skin from damage caused by free radicals and environmental stressors.[84] Biofuel, Cashew apple pulp can be used to produce biofuels such as ethanol. This is an emerging application of the cashew apple that has the potential to reduce dependence on fossil fuels and promote sustainable energy production.[17] Biogas is processed through the anaerobic digestion of organic material by anaerobic bacteria. It can be made either from biodegradable CA waste materials or by using its fresh juices.[17] Animal feed: Cashew apple pulp and seeds can be used as animal feed, especially for pigs and poultry. The pulp is high in fiber and nutrients, and it can help improve the digestive health of animals.[83]

Importance of Cashew Apple in Food, Nutrition, and Health

In areas where it has been extensively used, the cashew apple is a significant fruit that contributes to food and nutrition security and is well-known for its therapeutic and nutraceutical qualities. It has five times as much vitamin C[2, 3, and 13] as citrus juice and ten times as much as pineapple juice, making it a vital source of vitamin C.[43]

CA was reported as the primary source of vitamin C.[2,3,6,14] The CA's vitamin C content is about three to six times more vitamin C content in orange.[5,12] The fruits also contain β carotene, minerals such as calcium, and potassium, Table 1 Furthermore, the raw fruit is rich in acidity, rated as high acidic fruits range 0.18-0.79 titratable acidity, besides pH and total soluble solid ranges 3.4-4.7 and 6.5-20.36 Brix respectively.[5,6]

Table 1: Nutritional value of raw and processed CA

Nutrients	RCA raw juice[2,6]	YCA raw juice[2,6]	CA fruit Flour[58,88,90]	Dried CA[2,86,87]	CA wine[52,85]	CA jam[50,89]
Moisture %	85.92	86.38	6.52-11.42	4-13.8	-	30.38
Energy(Kcals)	-			3191	-	2721
Protein (%)	0.88	0.52-1.130	7.63-14.86	5.45	0.02	1.18-3.80
Fat (%)	0.30	0.27	3.70-5.18	3	-	0.10
Fiber(%)	-	-	5.91	6.65	-	1.02
Carbohydrate (%)	-	-	52.2-74.75	60.59	-	66.64
Total ash (%)	-	-	1.42	-	-	0.68
Cellulose (%)	3.56	3.34	-	-	-	-
Pectin (%)	0.86	0.98	-	-	-	-
Ca(mg/l)	85-144.52	99.7-133.1	192	80.14	-	-
Fe(/mg/l)	0.42-5.52	0.61-4	0.7	-	-	0.39
Mg(mg/l)	34.87-37.67	34.64-36.86	32.15	-	-	-
P(mg/l)	2.02-8.94	3.81-7.04	18.41	136.59	-	-
K(mg/l)	70.9-72.37	70.33-71.47	102.14	-	-	-
Na (mg/l)	29.44-35.26	31.5-34.34	-	-	-	-
Zn (mg/l)	1.9-3.59	1.94-2.36	5.1	-	-	505.14

Cu (mg/l)	0.04-0.66	0.11-0.53	-	-	-	4.26
β carotene (mg/l)	9.72-12.74	5.51-9.14	-	-	-	-
Total sugar(mg/l)	91151-219414	103519-215818	-	-	-	361760
Vitamin C(mg/l)	253.09-348.54	257.24-330	118.53	-	253-349	-
Vit. B1 (mg/l)	-	-	-	-	-	-
Vit. B2 (mg/l)	-	-	-	-	-	-
Vit. B3 (mg/l)	-	-	-	-	-	-
Total phenol(mg/l)	1591.84-2024.41		1066.55			
3653.03	-	1067-2887	13000	-		
Tannin(mg/l)	151.73-1361.50	502.30-1757.47	-	2665.9	22	-

Note: CAFP; CA fruit powder, RCA; Red CA, YCA; Yellow CA

Additionally, it contains anti-oxidants, fructose and glucose, salts, organic acids, amino acids, anacardic acids, and mineral salts.[14,43] Moreover, it reportedly has medical benefits, for example, its high tannin content makes it a viable treatment for chronic dysentery and sore throats. In addition, preventing cardiovascular disease and several types of cancer depends on phenolic compounds.[12] Moreover, CA flesh has anti-oxidant, anti-mutagenic, anti-bacterial, anti-fungal, and anti-tumour capabilities .[5,12,44]

Anti-Nutritional Factors in CA

Anti-nutritional factors are compounds present in most plants' food in varying amounts, and they pose health-related issues to humans or animals when consumed in high quantities. They inhibit optimal food nutrient utilization and reduce nutritional value.[71] Moreover, CA was also reported to contain a countable amount of ant-nutritional substances such as glycoside (20.65 to 26.61 mg HCN/100g), oxalate (28.7 to 32.7mg/100g), and tannin.[72,73] These factors affect human health; for instance, too much oxalic acid in the body prevents soluble calcium ions as the oxalate binds the calcium ions to form insoluble calcium oxalate complexes, which contributes to kidney stones formation.[74]

Tannin (polyphenol) can form tannin-protein complexes under certain pH conditions. The complexes are reportedly responsible for low protein digestibility,[71,75] inhibiting iron absorption,[75] and forming complexes with vitamin B_{12}[75] HCN can cause central nervous system dysfunction, respiratory failure, and cardiac arrest.[76]

At low concentrations, tannin has been shown to reduce nutrient availability and cause growth inhibition. In addition, tannin reduces d glucose and insulin responses to starchy foods, plasma cholesterol, and triglycerides.[77] Tannins have been associated with a reduction of cancer risks.[77] Despite this, the balance between plant bioactive and anti-nutrient beneficial and hazardous effects relies on their concentration, chemical structure, time of exposure, and interaction with other dietary components. Thus, they can be considered anti-nutritional factors with adverse effects or non-nutritive compounds with positive health.[77]

Anti-nutritional factors must be inactivated or removed if the values of food substances are to be fully maintained.[71] This can be done through preparation during cooking using methods like soaking, boiling for oxalate, peeling the skin of fruits and nuts for tannin[75] and roasting and boiling for HCN.[78] This will help to reduce these factors to a permissible level, which are 5mg/kg, 20mg/g, and 50mg/kg for oxalate, tannin, and HCN, respectively.[78]

Processing Methods for Cashew Apple Products and Market Availability

Different processing methods have been employed to produce different valued added products from cashew apple. These generate additional income for farmers outside of the sale of raw cashew nuts is one of the most important benefits of cashew agriculture. For every kilogram of raw nuts, 8 to 9 kilograms of cashew apples are added,[12] producing a sweet yet astringent juice. In order to reduce astringency

test ,value addition is paramount important as a range of products from the cashew apple have been reported by[45,46,47] obtained from various processing methods to produce food, soft and alcoholic beverages, animal feeds, and bio-energy products Table 2.

Table 2: Processing technique of CA products

S	Cashew apple Products	Unity Operation involved	Reference
1	Juice	Pressing	48
		Pressing, clarification using Polyvinylpyrrolidone(PVP)	43,46
		Blending, clarifying using gelatine, pasteurization	2
		Pressing, clarification using sago, gelatine, starch	43
2	Wine	Pressing, filtration, clarification using gelatine, fermentation	46
		Pressing, filtration, fermentation	49,50
3	Vinegar	Fermentation	18
4	Jam	Pulping and concentration through boiling	18, 46
5	Confectionaries (Cashew apple biscuit)	Baking	18
6	Chutney	Boiling	18,51,52
7	Pickle	Slicing, marination, boiling	18,53
8	Bioethanol	Pressing, sterilization, clarification using gelatine, filtration, and fermentation	17,54
		Blending, fermentation	55,56
		Drying, cooking, filtration, fermentation	57
9	Cashew apple Powder	Slicing, drying, grinding, sieving	56,57
10	Dried cashew apple Crips	Slicing, osmotic dehydration, Drying	41

Researchers[49] have reported the high market potential for cashew apple products such as juice, wine, jam, marmalades, and pickles if proper processing technologies are used to remove astringent, the bottleneck to its utilization. On an industrial scale, some nations, like Brazil and India, have made significant advancements in processing and marketing cashew apple goods such as juice, jam, and other derivatives.[49,59,60]

Additionally, it has been claimed that a limited number of primarily female-owned small businesses create cashew apple juice for the local market in Guinea-Bissau and the Casamance region of Senegal, but in extremely tiny amounts. Aside from women's widespread use of artisanal winemaking in Guinea-Bissau, the preparation of cashew apples is still primarily a social activity. Recently, the processing of cashew apples into various value-added products in this country has declined due to the unavailability of inputs like packaging materials such as glass bottles, astringent removal agents, and financing.[60]

Cashew gum is utilized to make chocolate pebbles in Ghana; nevertheless, more research has been recommended to determine the viability and sustainability of this practice.[59] Conversely, a fermented beverage from cashew apples is processed in Goa, India. The juice is extracted and fermented for a few days, then double distilled to a local beverage called *feni* or *fenny.* Similarly, cashew farmers from Mozambique make strong liquor, namely agua ardente (burning water) from cashew apples.[61,62]

Tanzania has limited information on cashew apples' consumption, storage, and processing.[63] Only two centers, namely Naliendele Research Station and Ndanda mission, located at the key producing region of Mtwara, are known to process a few cashew apples to juice, syrup, jam, pickle, and wine. Otherwise, a substantial proportion of cashew apples are left to rot in the field, fed to animals, or only a tiny proportion of apples are enjoyed as snacks during harvesting of the nuts to quench hunger and thirst, or locally fermented and distilled by individual farmers to local brews known as *uraka* and *nipa* in Swahili.[59] Additionally, cashew apples are dried and stored for later reconstitution with water, fermented, and distilled to a strong liquor, traditionally referred to as *gongo*.[62]

These local brews are unregulated, hence are produced in concealed as they are considered illegal and are subjected to substantial penalties, including jail sentences due to preparation, transportation, possession, or drinking. As a result, production and consumption are contained in very small vicinity and sold cheaply to only locally identified customers to minimize the chances of being caught by authorities.

Lack of processing expertise, supporting technologies, and supportive regulations make it challenging to produce safe, high-quality products for the domestic and international markets, contributing to the underutilization of CA.[6] The Tanzania Agricultural Research Institute-Naliendele (TARI-Naliendele), which hosts the cashew research program, has studied the product, technological, and market development of value-added cashew apple goods. The program, however, never advanced to the point of product development, and no private businesses have yet been established to undertake production.[59]

This review calls for investment opportunities and policy reform to embrace and empower local technologies, potentially resulting in improved, regulatable, commercialized products for well-being and social-economic growth. For example, besides the vast potential of various foods, beverage, and alcoholic products from cashew apples, there are potentials for processing bio-ethanol, which may complement local energy demands. Similarly, residual fruit filtrates can be fed to animals and poultry or used in commercial animal feed production.[59]

Economic Potentials for Cashew Apple

Economic potentials involve availability of raw materials which improve product sustainability, Figure 3, as the cashew apples contribute about 90% of the weight in comparison with the nut with 10 %.[9]

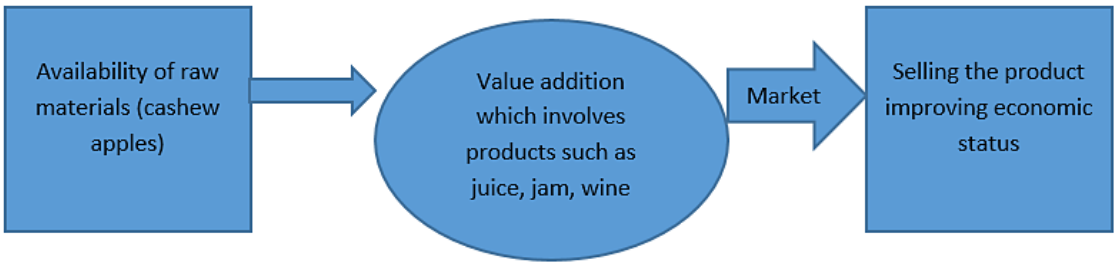

Fig. 3: Illustration of economic potential

Countries such as Brazil and India have recognized the potential of cashew apples. One of the world's biggest producers of cashew apple processing is Brazil. It is well known in jam, alcoholic drinks, and cashew apple juice.[64] The export of cashew-apple goods generates around 5 million dollars in revenue. Roughly, the country has 12 large juice extraction and processing companies as well as dozens of local bottler businesses.

This thriving industry employs an estimate of 2.5 thousand people and is projected to grow.[65] In Goa, India, the cashew apple is fermented and distilled to produce feni, a liquor.[64]

Furthermore, Kerala Agricultural University has advocated the value addition of cashew apples for use in various traditional products such as pulp, candy, and pickle through small, self-sustained

groups. For the internal market, the net profit obtained from this processing is around US$114.12 per individual per month. A kilogram of cashew nuts costs around US$ 2.01 in Maharashtra, India. A similar quantity of nuts can generate 10 kg of the cashew apple, resulting in an additional income of US$ 0.67 for the same amount, assuming a cashew apple price of US$ 0.06 per kg. If processed properly, the cashew apple can create additional revenue for the farmers through a variety of value-added products.[18] Revenue generated from the sale of these products could be comparable to that generated from the sale of nuts,[64] and hence farmers can rely on both the nuts and apples as sources of revenue for economic transformation.

In Tanzania, cashew apple production was 2,326,818 tones in 2019/2020 based on the nut production of 232,681.8 tones.[27] These volumes are expected to increase significantly by the year 2024[66] due to the government initiatives in introduction and campaigns for cashew trees cultivation in other 13 regions, namely, Singida, Dodoma, Iringa, Njombe, Songwe, Katavi, Tabora, Shinyanga, Kilimanjaro, Kigoma, Rukwa, Simiyu, and Mwanza[66] from the year 2019. Following success stories from the former growing regions of Mtwara, Lindi, and Ruvuma, the adoption of cashew cultivation in these later regions have been flourishing.[67]

The country also offers a dedicated cashew research center, the Tanzania Agricultural Research Institute (TARI)-Naliendele and Cashewnut Board of Tanzania (CBT), which provides continuous research for development support to farmers to ensure continuous production of cashew nuts, which in turn implies the production of cashew apples.[19] This means an assurance of raw materials for cashew apple processing and marketing, especially in places where there are no existing cashew apple products in the country and even a few in the regional market are imported. The country strongly supports agricultural production as they are considered key to social and economic transformation, central to closing the fresh produce seasonality barrier, and reducing the food and nutrition security gap for improved health. In the past ten years, the country has strategically positioned agro-industrialization as central to the economic development envisioned in the National Development Vision 2025[68] which has been implemented in two phases of Five-Years Development Plans II and III[69,70]

These plans require actual investment and the establishment of agro-processing industries, among which cashew apple is a virgin and promising sector. Like the government initiative on cashew nuts, a similar but context-specific intervention on cashew apples would double farmers' benefits from not only the cashew nuts harvest but also the cashew apple harvest.

Challenges Facing CA Processing and Utilization

The CA seasonal production is one of the most significant handicaps for the processing industry,[21] along with its astringent and acrid taste of the fruit attributed to high tannin content[79] has been hampering its consumer acceptability.

The limitation of CA utilization in product development is pest infestation due to nut borer, fruit flies, and thrips. Secondly, microbial infection is due to the delicate nature of CA skin. As the third factor, the fruit's physiology nature, which involves a drastic reduction in ethylene release rate and volatile compounds at the postharvest stage, is unique to CA. A sudden increase in abscisic acid at the pedicel and all over the fruit at the later stage of the development tends to reduce the retention capacity and firmness. Additionally, the tannin content in the CA fruits affects organoleptic characteristics, including palatability.

Besides, the limited utility of CA caused by high susceptibility to physical injury leads to microbial spoilage by yeast and fungi during harvest, transportation, and storage. More than 60 % of CA collected at the ripe stage exhibits moderate to massive damage. Thus, the CA storability is very poor, and complete spoilage can occur within hours after harvest. The fragmented and scattered nature of cashew plantations also sometimes creates problems in collecting and utilizing CA. After considerable delay, the collection of cashew nuts from fallen fruits also limits the availability of quality CA for processing purposes.[21]

However, the processing of CA into various value-added products has declined due to the unavailability of inputs like packaging materials

such as glass bottles, astringent removal agents, and financing.[80] UNIDO reported the unavailability of processing technologies and commercial production equipment as challenges responsible for continued underutilization.[81] Inadequate information on long-term economic benefits and market potentials for the fruit and its products also contribute to its underutilization[22,82]

Conclusion

Though highly important for food, nutrition and health, and economic transformation, cashew apples have been highly underutilized in countries where agricultural production processing has not been realized. Apart from processing, the consumption of fresh cashew apples in these countries remains a hunger- and thirst- quencher in the field during harvesting nuts, the gold product from the cashew tree. This critical underutilization is mainly attributed to a lack of, knowledge and awareness of its importance, cold chains allow transportation and processing technologies to diversify forms of consumption and extend shelf life. This review provides key information on cashew apple production and limitations to its utilization in Tanzania. It also summarizes utilization patterns and processing technologies in countries where cashew apples have been considered a potential product parallel to cashew nuts. It is expected that this documentation will contribute to creating awareness of the importance of cashew apples in social-economic, food, nutrition and health, thereby stimulating local consumption in places where they are produced, and that cold chain transportation is not required, call for interventions to empower local and invite new postharvest handling technologies including cold chain and processing to allow transportation, diversification and shelf-life extension.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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