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Cashew Wastes Biomass in Tanzania Auditing and Characterization: A potential bioresource for production of value-added products

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Abstract

Cashew waste biomass presents a valuable resource for production of value-added products. This study evaluated potential for valorization of cashew wastes (husks, apples and leaves) generated in Mtwara, Tanzania through integrating quantitative and laboratory analysis methods. Chemical composition of cashew waste analyzed were nitrogen, phosphorus, pH, moisture content, total organic matter, ash content, crude fiber, and conductivity. Nitrogen contents of cashew waste including husks, apples and leaves ranged between 1.46 – 2.58%, phosphorus was 0.03 – 0.38%, moisture content between 5.63-23.10%, and pH ranged between 4.44 -5.91. Solid wastes were characterized by crude fiber content in the range of 0.32-0.49 g, ash content between 6.65 – 14.24% and total organic matter content between 95-97%. Results showed that the annual generation of cashew wastes was estimated at 458,874 tons. Out of these, 66% were dried cashew apples, 33% cashew nut shells and 1% cashew husks. These wastes can be transformed into food, feed, bio-energy and bio-based products using bioconversion technologies in integrated and sustainable manner. A scheme for utilization of cashew waste into value added products has been proposed which contributes to environmental preservation. This approach offers a circular economic growth and aligns with global sustainable development goals by responsible consumption and production.

Key words: Cashew wastes; cashew apples; cashew husks; characterization; quantification.

Introduction

Cashew are cultivated in tropical regions of the world such as Northeast Brazil, Southeast Asia, islands in southern Indonesia, West Africa and East Africa including Tanzania, (Nikiema et al. 2020). Cashew is one of the major agricultural export crops and the largest foreign exchange earner in Tanzania. About 80% of cashew nut is estimated to come from Mtwara, Lindi and Ruvuma Regions (Mallya 2013).

The Government of Tanzania through the Ministry of Agriculture has recently made some initiatives to cultivate cashew nuts in other regions in the country, including Coast, Tanga, Dodoma, Singida, Mbeya, Morogoro, Iringa, Tabora, Kigoma, Katavi, and Songwe (Tanzania Cashew nut board report 2019/2020). Cashew nut production constitutes about 19% of cashew kernels and has relatively high processing waste constituting about 81% of remaining biomass (Tanzania Cashew nut board report 2019/2020). Processing wastes are composed of solid wastes such as cashew nut shells and cashew husks (testa). The industry also produces post-harvest wastes including, cashew apples and cashew leaves pruned during cultivation. In 2021, the national production of cashew nut was reported at 206,700 tons (BOT report 2020/2021), highlighting the crop's economic significance and the substantial waste generated for potential valorisation.

Based on cashew cultivated area for year 2021, it is estimated that a total of 2,597,931.26 tons of cashew wastes was generated, comprising of 301,782 tons of dried cashew apples 4,134 tons of cashew husks, 152,958 tons of cashew nut shells and 2,139,057.26 tons of cashew leaves and branches. Cashew wastes generated in Tanzania have been used for production of value-added products such as anti-corrosion coating from cashew nut shells (Magufuli 2009, Hamad and Mubofu 2015), bio-briquettes (Mwampamba et al. 2013), bioethanol (UNIDO 2011), biogas (Prabhudessai et al. 2013) and feed (Sruthi and Naidu 2023, Costa et al. 2009). Furthermore, studies (Aluko et al. 2022, Rabelo et al. 2009) reported that cashew apples have the potential to be processed into juice, syrup, jam, ice cream, candy, chutney, pickle, and other products. Cashew apples can also be utilized through biotechnology, which depending on the substrates and microorganisms can yield a variety of products such as wine, juice, bioethanol, enzymes, biosurfactants, probiotic beverages, lactic acid and oligosaccharides (Aluko et al. 2022, Rabelo et al. 2009). In addition, cashew husks (testa) offer broad application across diverse technological domains and serving as a source of phytochemical and other nutrients such as tannin or natural dyes which can be extracted and used in the leather industry, production of bioenzymes which have various application in food, cosmetics and pharmaceuticals industries (Zafeer and Bhat 2023, Sruthi and Naidu 2023). Cashew husk (testa) can also be used to make textiles, animal feed, insulation, as fuel for cooking or heating and as a potential source of bioactive compounds (Da Silva et al. 2022, Sruthi and Naidu 2023, Zafeer and Bhat 2023). This diverse range of uses underscores the significant potential of cashew waste valorisation in Tanzania.

Despite the potential of cashew waste biomass, there was no thorough quantification and characterization of cashew wastes that has been done before in Tanzania to guide their utilization through various conversions into value added bioproducts. Although, the quantity and compositions of cashew residues produced in other countries have been reported (Prommajak et al. 2014, FAOSTAT, 2022), it is only indicative and never universal as they vary considerably depending among other factors such as processing methods and soils conditions.

The primary objective of this study was to quantify and assess the quality of cashew wastes generated in Mtwara, Tanzania, so as to guide their utilization through various conversions into value added bioproducts. Specifically, this study focused on three key areas: the cultivation of oyster mushroom (*Pleurotus* HK-37), biogas production from the spent oyster mushroom (*Pleurotus* HK-37) substrate and biorefining of cashew waste biomass for the integrated production of food, animal feed and biofertilizer. These initiatives support the development of circular world bio-economy by enhancing resource efficiency and promoting environmental sustainability.

Material and methods

Waste quantification

Cashew waste quantification was undertaken through a field survey conducted in 2021 at the Tanzania Agricultural Research Institute (TARI) pilot and research farms in Naliendele, Mtwara. Data were collected on farm size, plant age, species and variety of cashew tree, waste generation rates and existing waste management practices. The survey focused on post-harvest wastes, including cashew apples, pruned cashew leaves and branches, as well as senescent leaves that had fallen prior to nuts harvest. Three cashew varieties were included in the assessment: *Anacardium ceylon*$_4$ (AC_4), *Anacardium zanzibar*$_2$ (AZA_2) and *Mozambique*. All collected waste materials were weighed before and after drying and subsequently stored for further processing and analysis.

For quantification of processing waste, twelve replicates, each consisting of one kilogram of raw cashew nuts were collected from different tree. The cashew nut processing procedure followed methodology described by Sruth and Naidu (2023), comprising five major steps as: (1) steaming of raw cashew nuts in hot steam for 10 minutes, (2) cooling at ambient temperature for 8 hours, (3) cutting to separate the shells and kernels with husks, (4) drying the kernels with husks in an in an oven at 70 °C for 8-10 hours and (5) peeling the husks from the cashew kernels.

Processing wastes, including cashew nut shells (CNS) and husks, were systematically collected, weighed and recorded at each processing stage to ensure accurate quantification. A subsample of 10 kilograms of each waste type were retained for laboratory analysis.

Analytical methods

The samples were analysed in triplicates to determine their physicochemical parameters using standardized protocols. Total solid (TS), volatile solids (VS), and ash content were determined by oven-drying and ignition method, respectively (APHA 2017). In addition, total carbon (TC) was analysed according to Allen (1989) and Nelson and Sommer (1996). Organic matter content was determined by dry combustion as described by Jiménez and García (1992) and Lyimo et al. (2002). Conductivity and pH were measured using a portable pH meter (HANNA-Italy). Total Nitrogen was determined by total kjeldahl technique using Micro Kjeldahl Equipment (GERHARDT-Germany). Moisture content and crude fiber (CF) was determined according to Mshandete (2011) and A.O.A.C method (1995) as follows;

A mass of about 5 g of each sample in triplicate were weighed in pre-conditioned crucibles; samples were dried at constant air oven of 105 °C for 24 hours. The loss in weight was used to determine moisture content and total solids and as shown in equation (i) and (ii) respectively.

$$\text{Moisture content (\%)} = \frac{\text{weight of sample} - \text{weight of sample at } 105\ ^{\circ}\text{C}}{\text{Weight of sample}} \times 100 \qquad \text{(i)}$$

$$\text{Total solids (\%TS)} = \frac{\text{weight of sample at } 105\ ^{\circ}\text{C}}{\text{Weight of sample}} \times 100 \qquad \text{(ii)}$$

The same sample was heated in a furnace at 550 °C for two hours in order to determine volatile solids (VS) and ash contents as shown in equation (iii).

$$\text{Volatile solid (\%VS)} = \frac{\text{weight of sample at } 105\ ^{\circ}\text{C} - \text{weight of sample at } 550^{\circ}\text{C}}{\text{Weight of sample}} \times 100 \qquad \text{(iii)}$$

Total carbon was determined by dry combustion method as described by Allen (1989). A mass of about 1 g of each sample in triplicate previously dried at 80 °C was heated at 600 °C for six hours. The difference in weight was used to determine total carbon content as described in equation (iv).

$$\text{Total Carbon (\%)} = \frac{100 - (\text{\% weight of sample at } 600\ ^{\circ}\text{C})}{1.8} \qquad \text{(iv)}$$

Total Organic Matter (TOM) was determined using dry combustion method as described by Lyimo et al. (2002). A mass of about 1 g of each sample in triplicate previously dried at 105 °C was heated at 550 °C for four hours, shown in equation (v).

$$\text{TOM (\%)} = \frac{\text{weight of sample at } 80\ ^{\circ}\text{C} - \text{weight of sample at } 550\ ^{\circ}\text{C}}{\text{Weight of sample}} \times 100 \qquad \text{(v)}$$

Total fibers were determined by ignition of previously oven-dried sample at 800 °C for 45 minutes. There after allowed to cool to room temperature before further ignition at 400 °C for

30 minutes (Mshandete 2011), shown in equation (vi).

$$\text{Total Fibers (\%)} = \frac{\text{weight of sample at 800 °C}}{\text{Weight of sample at 105°C}} \times 100. \qquad \text{(vi)}$$

Conductivity and pH were measured using a portable pH meter (HANNA-Italy). About 2 g of a samples were weighed then mixed thorough with distilled water. After calibration of pH meter, equilibrium between electrodes and sample was established by stirring sample to ensure homogeneity; the samples were stirred gently to minimize carbon dioxide entrainment. The electrodes of pH metre were immersed into sample for 1 min and pH measurement were taken into three successive portions of sample.

Total nitrogen was determined by Kjeldahl method using MicroKjeldahl Equipment (GERHADT, Germany) whereby, in digestion about 1g of a sample was weighed and transferred to the labelled digestion tube in triplicate, in each batch a tube without sample was used as blank test. Thereafter, missouri catalyst (2 Kjeldahl tablets) and 20 ml of concentrated sulphuric acid (98%) were added into each tube. The tubes were then placed in the Kjeldatherm digestion unit connected to the fume removal manifold. In addition, turbosog unit for fume collection was prepared by adding approximately 1000 ml of 10% NaOH with indicator to the washing bottle and approximately 400 ml of 10% NaOH with indicator to the condensate bottle of the turbosog unit. Turbosog unit was then switched on after ensuring tap water is flowing through. The fume hood was switched on and temperature of the Kjeldatherm digestion unit was set to 420 ± 20 °C and samples were digested for 1 hour at 420 ± 20 °C.

The samples were then removed from heat and allowed to cool for 20 minutes.

In addition, distillation of sample was done using vapodest distillation unit which was prepared by filling the water tank with distilled water and Sodium hydroxide tank with 40 percent Sodium hydroxide and was turned on. Digestion tube was filled with 50 ml of distilled water and steam inlet tubing was inserted. In addition, the distillate outlet tubing was inserted into an empty Erlenmeyer flask and placed into position. Protection door was closed and distillation system was switched on. Sodium hydroxide solution was run into the digestion tube afterwards digestion tube and Erlenmeyer flask was removed hence the vapodest distillation system was primed. Samples and blank were distilled by filling 50 ml of boric acid and water was added into Erlenmeyer flask to a total volume of approximately 80 ml and the instrument was switched on to start distillation process. After the distillation process was completed digestion tube and Erlenmeyer flask with distillate was removed from instrument.

The content of sample in the Erlenmeyer flask was titrated with 0.1M Hydrochloric acid standard solution after adding a few drops of methyl red indicator solution and amount of titrant used was recorded. The endpoint was reached when the colour of the titrated contents turned to traces of pink colour. The amount of acid used was recorded to the nearest 0.05 ml for the blank test (Vb) and for each sample (Vs).

The amount of nitrogen in the sample was calculated using the equation (vii);

$$\text{Total Nitrogen (\%TKN)} = (Vs\text{-}Vb) \times M\,(HCl) \times 1 \times 14.007\ (W \times 10) \qquad \text{(vii)}$$

Where, Vs = volume (mL of HCl used to titrate sample, Vb = Volume (mL) of HCl used for the blank test, M (HCl) = Molarity of HCl, I = Acid factor, 14.007 = Molecular weight of N, 10 = conversion from mg/g to percentage and W = weight of sample (g).

Data Analysis

Analysis of variance was used to determine mean differences of cashew waste across cashew varieties. Cashew waste quantity data was checked for normal distribution and homogeneity of variances within cashew variety groups to comply with assumptions of ANOVA. A p-value of less than 0.05 was considered to indicate statistical significance.

Result and Discussion

Quantification of cashew post-harvest and cashew processing wastes

The quantity and composition of cashew wastes generated are influenced by multiple factors including type of soil, availability of soil nutrients, variety, seasonal variations, temperature, humidity and other climatic factors. Based on cashew cultivated area of 1,074,097 hectares (ha) for year 2021, with 68 trees per hectare (www.kilimo.go.tz), resulted in production of 206,700 tons of cashew nut (BOT report 2020/2021). The types and quantity of cashew wastes produced are shown in (Figure 1, 2 and 3). The estimated total annual production of cashew wastes for year 2021, was 2,597,931 tons. Currently, these wastes are used as raw materials for production of wine, cashew apple juice (Aluko et.al 2022), bioethanol (Jeyavishnu et al. 2021, UNIDO 2011) animal feeds (Zafeer and Bhat 2023, Da Silva et al. 2022, Sruthi and Naidu 2023), anti-corrosion coating (Magufuli 2009, Hamad and Mubofu 2015) and bio-briquettes (Mwampamba et al. 2013). While some of these wastes are consumed worldwide about 90% are disposed in the environment (Sruthi and Naidu 2023, Honorato et al. 2007).

A case study for cashew nut production and processing at Tanzania Agricultural Research Institute (TARI), Naliendele, Mtwara, revealed substantial waste generation from cashew nut production and processing including cashew apples, husks, cashew leaves, cashew branches and cashew nut shells. Based on field data, it is estimated that 1-hectare cashew nut farm has 68 trees and production of 1-ton cashew nuts resulted in generation of 1.46 tons of cashew apples, 0.02 tons of cashew husks, and 0.74 tons of cashew nut shells. In addition, further quantification at a small scale demonstrated that production of 1kg of cashew nut produced from three cashew varieties namely *Anacardium ceylon$_4$* (AC_4), *Anacardium zanzibar$_2$* (AZA_2) and *Mozambique* resulted in generation of 1,457.09g of cashew apples, 735.03g of cashew nut shells, and 22.14g of cashew husks (Figure 1 and 2). Furthermore, it was estimated that the quantity of cashew leaves and branches produced per one tree were 30,200g in *Anacardium ceylon$_4$* (AC_4); 27,530g in *Anacardium zanzibar$_2$* (AZA_2) and 30,130g in *Mozambique* variety (Figure 2). Statistical analysis revealed significant difference ($p < 0.05$) in weights of cashew shells and cashew apples produced across varieties. However, no significant difference ($p > 0.05$) were observed in the weights of other types of wastes (husk, leaves and branches) produced across cashew varieties.
Thus, the quantities and characteristics of cashew waste generated in Tanzania, which could guide their valorization into various valuable products such as food, feed, bio-energy and green chemistry are being reported.

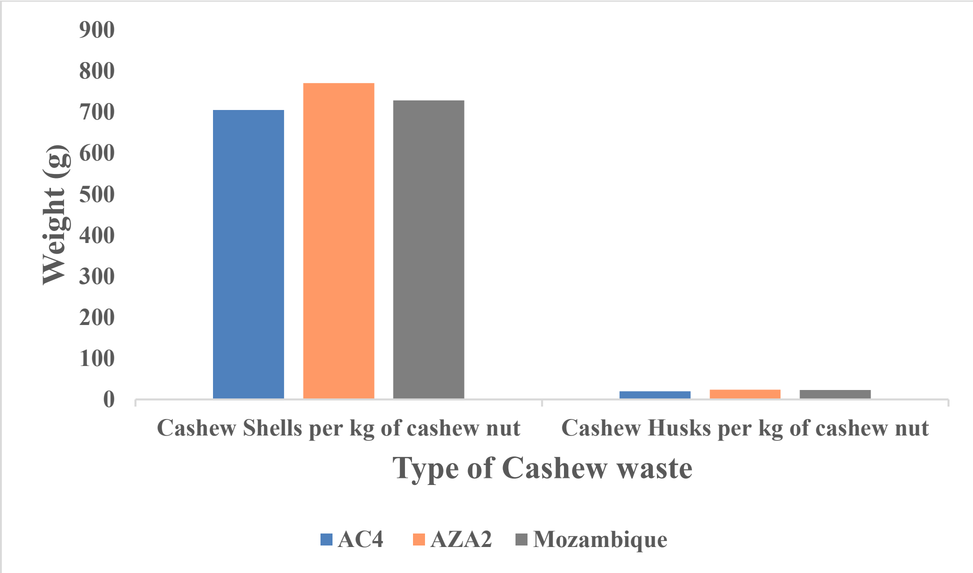

Figure 1: Quantity of processing cashew waste fractions generated in Mtwara, Tanzania in 2021

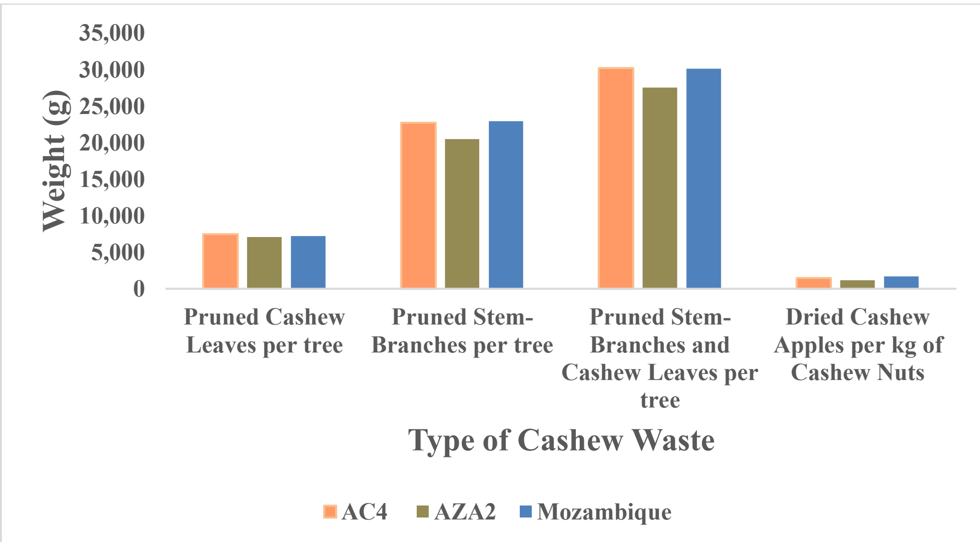

Figure 2: Quantity of post-harvest cashew waste fractions generated in Mtwara, Tanzania in 2021

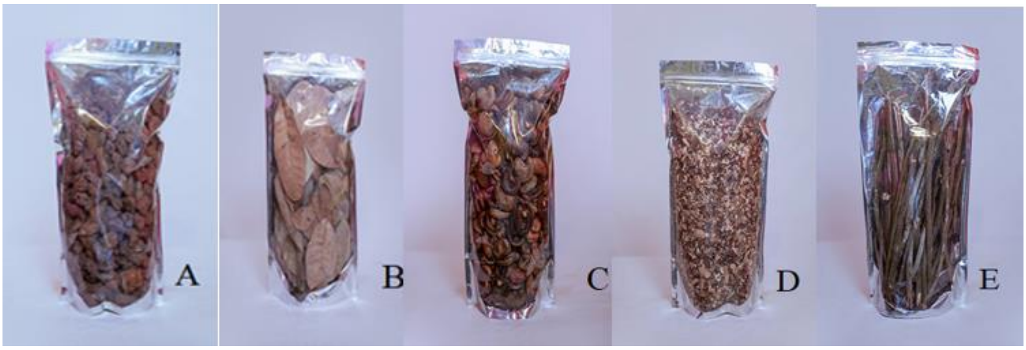

Figure 3: Types of cashew waste generated. (A) dried cashew apples (B) dried cashew leaves (C) Cashew shells (D) cashew husk (E) stem and branch in Mtwara, Tanzania in 2021

Table 1: Quantity of processing and post-harvest cashew waste fractions generated (Mean ± SD, n=3)

	Processing Waste		**Post-Harvest Waste**			
Cashew Variety	Cashew Shells (g/kg)	Cashew Husks (g/kg)	Dried Cashew Apples (g/kg)	Pruned Cashew Leaves per Tree	Pruned Stem-Branches per Tree	Pruned Stem-Branches and Cashew Leaves per Tree
AC_4	705.5±3.83	20.17±2.21	1,480.5 ±0.64	7,470 ±1.09	22,730 ±4.03	30,200 ±5.03
AZA_2	770.92+10.05	23.58±4.01	1,183.80 ±0.29	7,070 ±1.59	20,470 ±7.61	27,530 ±9.20
Mozambique	728.67±17.97	22.67±4.44	1,706.96 ±0.76	7,200 ±0.37	22,930 ±1.72	30,130 ±2.08
Mean	735.03	22.14	1,457.09	7,246.67	22,043.33	29,286.67
p-value	0.0000	0.0773	0.0162	0.9382	0.8671	0.8877

AC_4 = *Anacardium* c*eylon$_4$* and AZA_2 = *Anacardium zanzibar$_2$*

Suitability of any biomass as feedstock for utilizing to bioproducts usually depends on its chemical characteristics. The chemical compositions of the cashew wastes are shown in (Tables 2). Generally, the solid fractions were rich in biodegradable substances in terms of volatile solids (VS) in the range of 85 - 93%. The dried cashew leaves had the highest VS (93.35%) content while cashew husk had the least (85.76%) and about 54 % in terms of total organic carbon. The dried cashew apples had a VS content of 87%. These values are similar to those obtained from previous studies (Nikiema et al. 2020). The content of total solids (TS) in all streams ranged from 76 % to 94% respectively, making these wastes potential substrates for biogas production because according to Singh et al. (1993), the high the volatile solid and total solid content the more biogas generated from the substrate. The high values of organics contained in the cashew waste fractions is indicative of their potential for valorization and as feedstocks for a biorefinery that could produce food (mushroom), feed, biofuels (biogas, bioethanol) and other bioproducts (Da Silva et al. 2022, Magufuli 2009, Hamad and Mubofu 2015, UNIDO 2011, Prabhudessai et al. 2013, Aluko et al. 2022, Rabelo et al. 2009, Sruthi and Naidu, 2023, Zafeer and Bhat, 2023). Furthermore, the cashew wastes fractions were characterized by crude fiber content in the range of 0.32-0.49 g and total organic matter content in the range 95-97%, these values are similar to those obtained from previous studies (Mako et al 2020). The dried cashew apples were found to be acidic (pH of 4.44). Percent nitrogen contents of the waste fractions including cashew husks, cashew apples and cashew leaves ranged between 1.46-2.58% and their phosphorus content ranged between 0.03-0.38%. Similar range of nitrogen content has been reported earlier (Chermahini. 2012). To obtain chemically balanced suitable substrates for the proposed bioproducts, particularly in terms of C:N ration, blending of the various nitrogen and carbon rich fractions is necessary. Cashew husks have low carbon to nitrogen ratio 21.07, followed by dried cashew apples which was 30.40 while that of cashew leaves was 37.19, hence blending both which are nitrogen and carbon rich offers optimum substrate composition for mushroom cultivation and anaerobic digestion. Similarly, these fractions had relatively very low crude fiber content ranging between 0.32 – 0.49%. This characteristic makes the fractions to be categorized as heavily biodegradable materials which can be bioprocessed without pre-treatment when anaerobic digestion is an option (Mshandete et al. 2013).

Table 2: Chemical characteristics of cashew waste fractions (Mean ± SD, n=3)

Parameter	Dried Cashew Apples	Cashew Husks	Dried Cashew Leaves
Total Solids (TS %)	76.90 ± 0.96	94.37 ± 0.06	90.12 ± 0.06
Volatile Solids (% TS)	87.38 ± 3.34	85.76 ± 4.54	93.35 ± 0.16
Moisture Content (%TS)	23.10 ± 0.96	5.63 ± 0.06	9.88 ± 0.06
Ash Content (%TS)	12.62 ± 3.34	14.24 ± 4.54	6.65 ± 0.16
Total Carbon (%TS)	52.59 ± 0.01	54.36 ± 0.08	54.30 ± 0.12
Total Organic Matter (%TS)	96.03 ± 0.73	97.02 ± 0.11	95.13 ± 0.32
Crude Fiber	0.49 ± 0.01	0.32 ± 0.04	0.37 ± 0.01
Total Kjedahl Nitrogen (%TKN)	1.73%	2.58%	1.46%
C:N	30.40	21.07	37.19
Total Phosphorus (%)	0.11%	0.38%	0.03%
pH	4.44 ± 0.06	5.91 ± 0.06	5.37 ± 0.03
Conductivity (μS/cm)	1.75 ± 0.26	2.20 ± 0.03	2.62 ± 0.35

μS/cm = microsiemens per centimetre); C:N = carbon to nitrogen ratio); TS = total solids; pH = potential of Hydrogen.

Proposed integrated utilization of cashew wastes

Management of Cashew waste is an important aspect for reduction of impact to the environment and sustainable utilization for production of value added products. Due to their richness in some nutrients and compounds, cashew wastes can be effectively used as a substrate for producing high-value-added products in the biorefnery context. Within this concept, modern green technologies can provide an attractive alternative to face the economy's challenges and solve environmental problems related to the inadequate management of the cashew biomasses (Sharma et al. 2020, Da Silva et al. 2022).

Depending on the nature of their compositions some of these wastes are already being utilized for generation of energy from cashew apples in the form of ethanol (Honorato et al. 2007, Jeyavishnu et al. 2021), production of leather using tannin extracted from cashew testa (Da Silva et al. 2022, Sruthi and Naidu 2023, Zafeer and Bhat 2023) and production of a wide range of functional products which are useful as therapeutic agents, such as neurotransmitter, anti-hypotensive, anti-cancer from cashew nut shell liquid (Anilkumar, 2017). Other current uses are production of wine, bio-fertilizers, enzymes, biosurfactants (Rocha et al. 2007), probiotic beverages, lactic acid, oligosaccharides (Rabelo et al. 2009). In addition, these wastes (Figure 4) could also be used in industrial production of food, cosmetic and pharmaceuticals from sequential extraction of biomass to generate high yield and pure product (Mitra and Mishra, 2019).

On the basis of the results of this study, an innovative approach is proposed which involves blending different ratios of the three cashew wastes namely; cashew apples, cashew husks and cashew leaves supplemented with cow dung manure and effective microorganisms as substrates for mushroom cultivation. Followed by utilization of spent mushroom substrate (i.e solids remains after mushrooms harvested) as feedstock for biogas production during anaerobic digestion.

The biogas digester effluent known as biogas manure (a byproduct obtained from biogas digester) after anaerobic digestion of organic matter for production of biogas rich methane) is valuable biofertilizer. Such an integrated innovative approach (Figure 4) processing multiple waste streams into value added by products offers sustainable economic and environmental benefits (Margaritan et al. 2009, Da Silva et al. 2022, Sruthi and Naidu 2023, Zafeer and Bhat 2023). Spent mushroom residues are traditionally discarded as waste, creating an environmental nuisance. The utilization of these wastes for production of biogas and other value added products such as insect protein in the form of black soldier flies's larvae or prepupae, crickets, cockroaches, fluvic acid rich biofertilizer, enzymes, biochar and feeds in a biorefinery concept could help to alleviate the environmental problems while generating more income for the mushroom growers.

Valorization through circular bioeconomy is yet another option of utilizing the wastes that is proposed for improved energy efficiency and alternative uses for the wastes and additional income generation while reducing the GHG (greenhouse gas) emissions and minimizing the use of fossil resources as stated in United Nations sustainable development goals and sub-goals on environmental protection and climate change (Hetemäki, 2017, Yaashika et al. 2022). Contrary to the current practices of utilizing waste generated by the cashew waste industry, the proposed approach and other already proposed approaches by other researchers (Magufuli 2009, Hamad and Mubofu 2015, UNIDO 2011, Prabhudessai et al. 2013, Aluko et al. 2022, Rabelo et al. 2009, Prommajak et al. 2014, Da Silva et al. 2022, Sruthi and Naidu 2023, Zafeer and Bhat 2023) give additional options for more products giving the flexibility in choices for utilizing the cashew wastes, which is an additional competitive advantage.

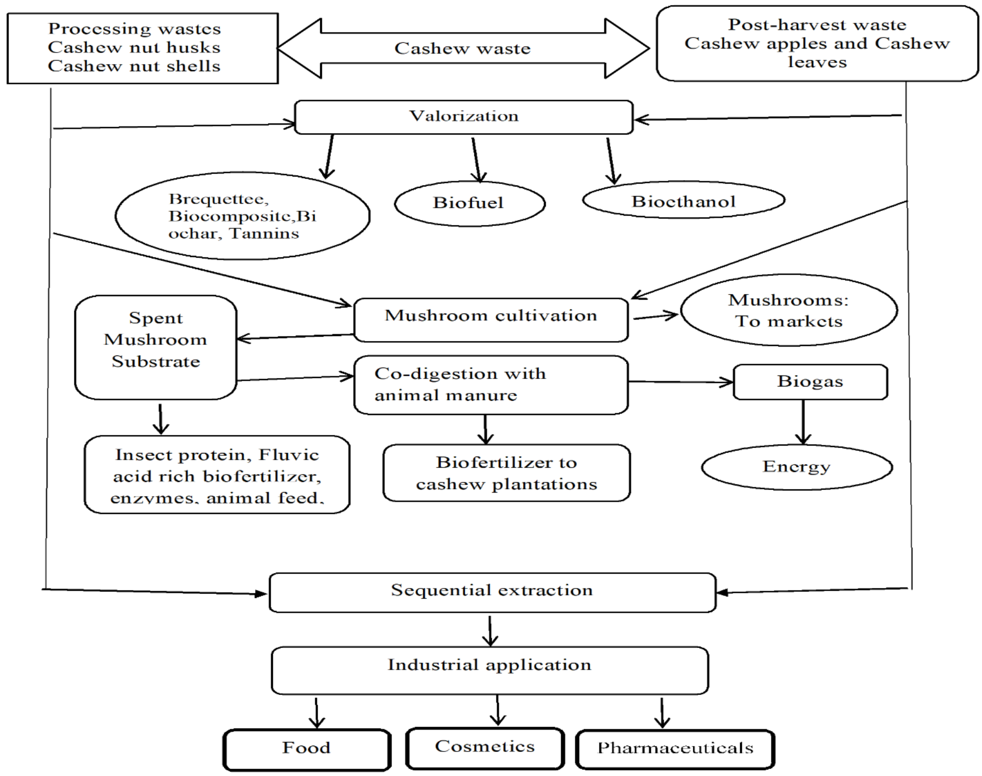

Figure 4: Proposed integrated utilization of cashew post-harvest and processing wastes integration across applications/multiple end products value added cycles.

Conclusion

Cashew nut production in Mtwara, Tanzania produces large quantities of wastes which have negative impact on the environment and economy. When not disposed into the environment untreated, their use is still limited to food, fuel and animal feed. The results of this study reports for the first time the characteristics of cashew wastes biomass generated in Tanzania. Analysis indicates that cashew wastes have high total solids, volatile solids, organic carbon and organic matter with relatively low fiber content. Based on these characteristics, they are a potential bioresource for use in several conversion processes for producing valuable products which can also increase the profit helping to establish a circular economy and environmental management. The wastes generated by cashew processing industries are currently available and in abundance for exploitation by valorization into food, feed, bio-energy and green chemistry.

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Conflicts of interest

The authors declare that there are no conflicts of interest in this study

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