VALORIZATION OF CASHEW NUT PROCESSING BYPRODUCTS: DEVELOPING VALUE-ADDED PRODUCTS

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Abstract. *This study investigates the valorization of by-products generated during cashew nut processing within the agro-industrial sector, utilizing the case study of the Amigos do Bem, a non-governmental organization operating in the semi-arid region of Ceará, Brazil. The research aims to develop value-added products from residues such as cashew nut skin, shells, cashew apple waste, and processing by-products, thereby addressing both environmental sustainability and socio-economic development. Laboratory analyses were performed to assess the safety and feasibility of producing food-grade analogues. Field visits, process mapping and material characterizations provided the identification of residue sources and potential applications in food, pharmaceutical, and industrial domains. The study highlights the pivotal role of integrating agro-industrial residue management with community-driven initiatives to promote sustainable development and income generation. Challenges and future prospects related to scaling production and expanding residue valorization beyond food applications are also discussed.*

Keywords: Agro-industrial residue, By-products, Cashew nut, Sustainable development, Value added products.

Introduction

Global food waste poses a critical challenge to both environmental sustainability and food security. According to the United Nations Environment Programme (UNEP, 2024) the 2024 Food Waste Index Report accounted that the global food waste amounts to approximately 1.05 billion ton each year, equivalent to discarding food worth about US$1 trillion annually. This food waste is responsible for 8 to 10 percent of global greenhouse gas emissions, nearly five times the emissions from the aviation sector. Meanwhile, around 783 million people worldwide suffer from hunger annually (UNEP, 2024).

Approximately 38% of total food waste consists of byproducts, which mainly arise during food production and require proper management to avoid environmental harm. These byproducts typically comprise nutrient-rich residues such as peels, seeds, shells, and pulp. Traditionally, they are repurposed as animal feed or fertilizers due to their valuable composition (Kim *et al*. 2022).

Emerging biotechnological approaches for valorizing food processing byproducts (FPBs), such as microalgal transformation, hold significant promise for overcoming current challenges. This innovative process converts low-value byproducts into high-value functional food ingredients while offering a sustainable and cost-effective alternative to conventional waste disposal. Additionally, it reduces environmental impact by diverting waste from landfills and supports the circular bioeconomy by creating new economic opportunities through resource recovery (Kim et al., 2022).

Amigos do Bem is a non-governmental organization (NGO) operating in the semi-arid region of Northeast Brazil, specifically in the municipalities of Mauriti, Inajá, Catimbau, and Torrões. This region ranks among the lowest in Brazil in terms of Human Development Index (HDI), with an average HDI of 0.487. For context, Switzerland, the country with the second highest HDI in the world, has a value of 0.946, while the Democratic Republic of Congo, ranked 138th, has an HDI of 0.608 (Amigos do Bem, 2023).

According to the Amigos do Bem portfolio document (Amigos do Bem, 2023), their mission is "to transform lives through education and self-sustainable projects capable of promoting local development and social inclusion, thereby eradicating hunger and misery." To fulfill this mission, the organization focuses on key areas including food security, education, work and income generation, water, housing, and health. Quantitative data about the impact of the NGO is described in Figure 1.

Figure 1- Social impact data

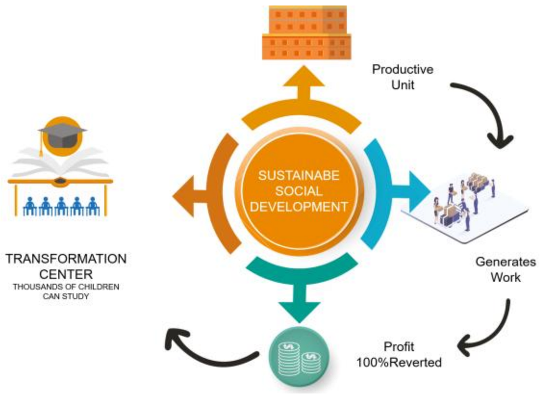
Source: Amigos do Bem (2023 – Adapted)

A core component of their work is the “Sustainable Social Development Model”, which leverages cashew nut processing factories to create employment and generate income. The profits from these productive activities help sustain the NGO’s social projects, particularly their educational programs, ensuring long-term community impact (Figure 2).

This study focused on the *Amigos do Bem* cashew nut processing factory in Mauriti as a case study to explore methods for creating value-added products from byproducts generated during processing.

According to the Food and Agriculture Organization of the United Nations (FAO), cashew nut production spans approximately 35 countries worldwide, with Brazil ranking as the sixth largest producer by volume. Consequently, the approaches developed in this study have the potential to be adapted and replicated in these cashew-producing countries to enhance the utilization of byproducts and add value across global supply chains (FAO, 2023).

Figure 2 - Sustainable social development model



Source: Amigos do bem (2023 – Adapted)

Objective

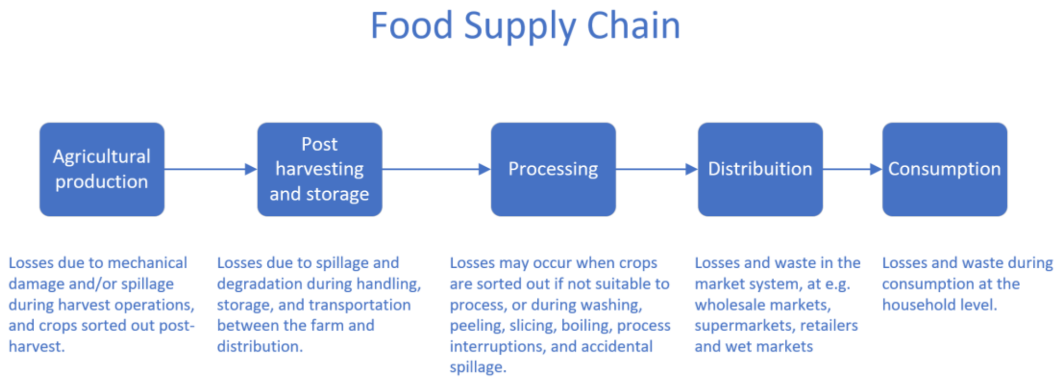
This research intends to examine the potential for transforming cashew nut processing byproducts into value-added products, with an emphasis on applications in the food industry using decontamination methods.

Development

In order to gain a comprehensive understanding of *Amigos do Bem* production process, it was necessary to conduct on-site visits to their facility in Mauriti, Ceará, Brazil. Accordingly, two field visits were conducted, one in 2023 and another in 2024, accompanied by Professor Tribess. During these visits, interviews were held with the factory manager and operational staff. Additionally, relevant process documentation was reviewed, and photographic and video records were taken with the purpose of mapping and analyzing the production processes and associated residues.

According to Gustavsson *et al*. (2011), food supply chains consist of five main activities, each characterized by specific types of food losses and waste (Figure 3).

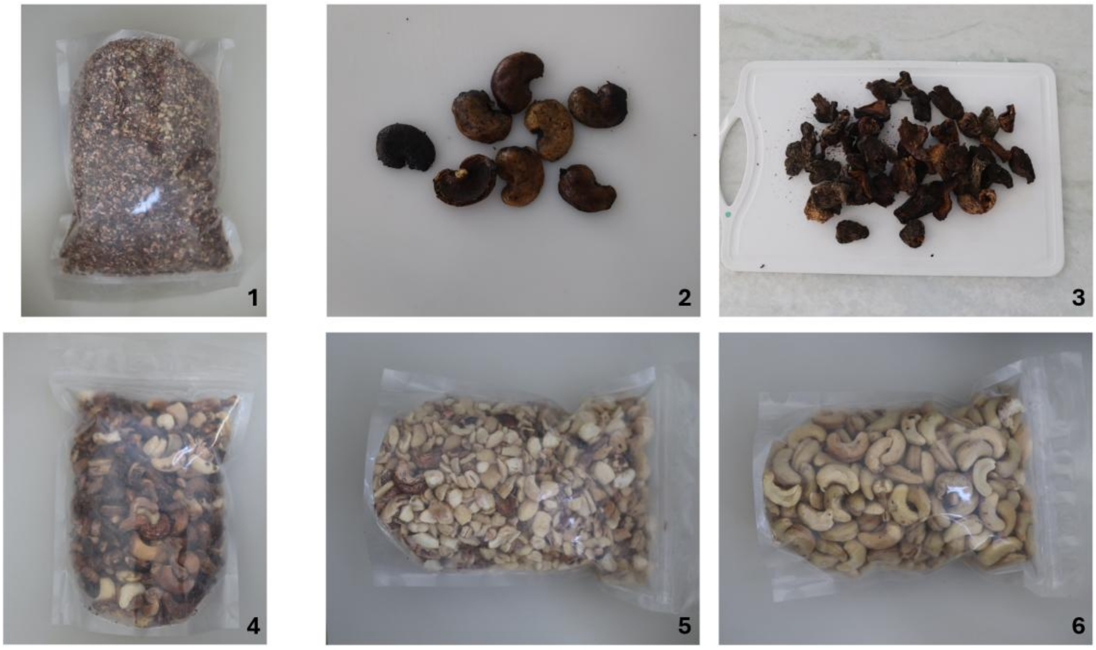
Figure 3 - Food supply chain



Source: Gustavsson (2011 - Adapted)

After the field visits to one of the *Amigos do Bem's* factories, six samples of the production waste were handled, represented in Figure 4. Most of these residues originated from the processing stage, except for the cashew apple residue, which derives from agricultural production.

Figure 4 - Cashew nut wase of production



Source: Author (2024)

The residues include cashew nut skin (1), cashew nut shells (2), cashew apple waste (3), rotten cashew nut (4), broken kernels and dust (5) and oily cashew nut (6). Most of the waste originates from the processing stage, whereas residue (3) specifically comes from the agricultural production phase, particularly during harvesting.

According to academic studies, the residues presented have diverse applications, which are summarized in the Table 1.

Residues 1, 2, and 6, corresponding respectively to cashew nut skin, shell, and oily cashew nut, fall outside the scope of the present study due to their primary applications being predominantly outside the food industry. Additionally, no scientific literature was found regarding the applications of residue 4.

Research into cashew apple waste (residue 3) began due to its low utilization, with Brazil exhibiting the highest utilization rate at 15% (UNCTAD, 2021), meaning that 75% of production remains as residue. Due to the large volume of this waste, studies were conducted to identify possible uses. However, the extensive presence of sand inside the peduncle after multiple washing stages (Figure 5) prevented the advancement of value-added food product development.

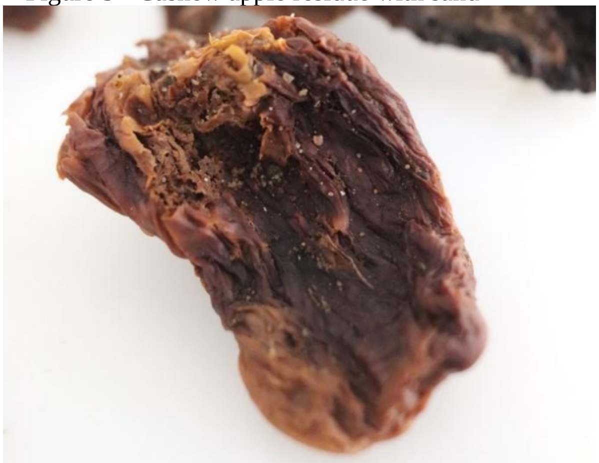
Table 1 - Cashew and cashew nut residues and their potential applications

Residue number	**Description**	**Applications**	**Reference**
1	Cashew nut skin	➢ Natural antioxidants ➢ Natural antimicrobial	Cesarettin (2025)
2	Cashew nut shells (cashew nut shell liquid - CNSL)	**Health:** ➢ Pharmaceuticals (anticâncer, antibacterial & alzeimers desease) **Industrial applications:** ➢ Resins ➢ Plastics ➢ Biodiesel ➢ Antioxidants ➢ Antimicrobials	Cesarettin (2025) **health** & Kyei (2023) **Industrial applications**
3	Cashew apple waste	➢ Food additives (fibre, anacardic acid, carotenoids, and vitamin C) ➢ Dietary supplements ➢ Fiber extraction	Cesarettin (2025)
4	Rotten cashew nut	Not found in literature	-
5	Broken kernels and dust	Plant based food ➢ Ice cream ➢ Cocoa cream ➢ Functional beverages ➢ Yoghurt/milk ➢ Gluten-free baked goods ➢ Food additives ➢ Candy bars ➢ Plant-based protein	Cesarettin (2025)
6	Oily cashew nut	CNSL extraction **Industrial applications:** ➢ Resins ➢ Plastics ➢ Biodiesel ➢ Antioxidants ➢ Antimicrobials	Kyei (2023) **Industrial applications**

Source: Author (2025)

The broken kernels and dust possess potential applications within the food industry, therefore, this study aims to investigate the potential applications of residue 5, consisting of broken cashew kernels and dust, with a focus on its utilization in the food industry. Specifically, this research will concentrate on exploring the development of cashew nut spreads produced from this residue.

Figure 5 - Cashew apple residue with sand



Source: Author (2024)

According to Rodríguez *et al*. (2021), despite the benefits associated with reintroducing such products into the food supply chain, it is essential to assess consumer safety. This entails the evaluation of physicochemical indicators, including moisture content, acidity (pH), ash content, color, texture, and nutritional composition, as well as microbiological parameters, such as total aerobic mesophilic bacteria, presence of pathogens, indicator organisms, and microbial counts benchmarked against regulatory standards. Common contaminants identified include pesticides, fungicides, mycotoxins, heavy metals, and persistent organic pollutants.

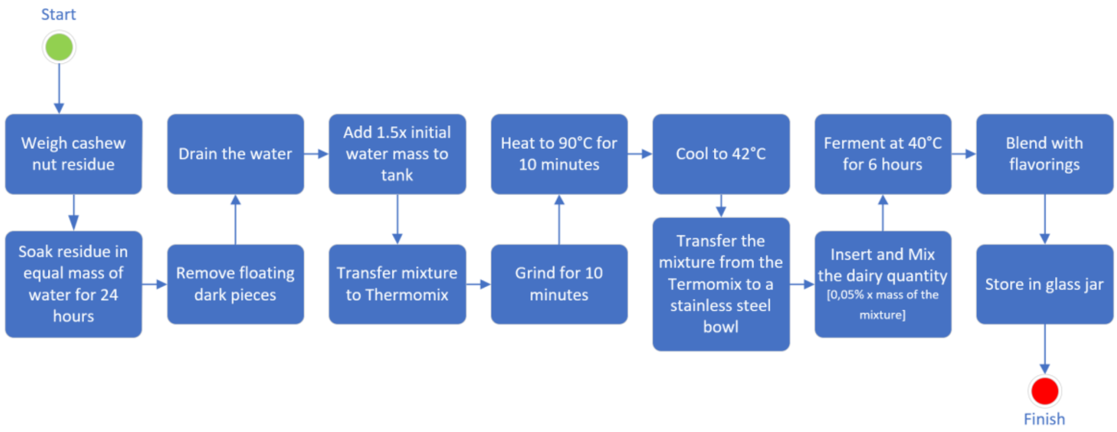
The presence of contaminants can be prevented and food safety enhanced through the application of an effective decontamination method. According to Aliya *et al*. (2021), the most common method of decontamination is the thermal processing to eliminate pathogenic and spoilage causing microbes in food products.

The presence of contaminants can be prevented and food safety enhanced through the application of appropriate decontamination methods. According to Aliya *et al*. (2021), thermal processing remains the most widely utilized technique for decontamination, primarily aimed at eliminating pathogenic and spoilage-causing microorganisms in food products.

Utilizing the research of Braitmaier (2024) as a reference, this study explores the potential to produce a value-added cheese analogue using broken cashew kernels and dust (residue 5). The plant-based cheese alternative production process is detailed in Braitmaier’s article, which has been adapted here to include a thermal decontamination method as illustrated in Figure 6.

The production of cashew nut cheese spread analogue begins by measuring the mass of cashew nut residue using a calibrated digital scale. The residue is then submerged in potable water at a 1:1 ratio (water to residue by mass) and allowed to hydrate for 24 hours at ambient temperature. Following hydration, any floating particulate matter or discolored fragments are skimmed off and discarded to ensure uniform quality. The mixture is then filtered to remove excess water, retaining only the hydrated cashew nut residue for further processing. Next, potable water is added to the processing tank in a volume equal to 1.5 times the initial mass of the residue, standardizing the mixture concentration.

Figure 6 - Cashew nut cheese spread process



Source: Author (2025)

The hydrated residue and water mixture is transferred into a Thermomix, or equivalent high-shear mixer, for homogenization. The mixture is processed at high speed for 10 minutes to achieve a uniform consistency. It is then heated to 90°C and maintained at this temperature for 10 minutes to ensure thermal decontamination. After heating, the mixture is gradually cooled down to a target temperature of 42°C, monitored with the integrated Thermomix thermometer, to ensure optimal conditions for subsequent fermentation. The cooled mixture is transferred from the Thermomix into a sterile stainless-steel bowl for further processing.

Once transferred to the stainless-steel bowl, the processed mixture is aseptically inoculated with the specified quantity of dairy starter culture (Lactobacillus acidophilus LA-5, Bifidobacterium BB-12 and Streptococcus thermophilus) to initiate fermentation, ensuring even distribution throughout the substrate. The inoculated mixture is then incubated at 40°C for 6 hours in a controlled fermentation chamber, providing optimal conditions for microbial growth and acid production. Upon completion of fermentation, the mixture is thoroughly blended with selected flavoring agents to achieve homogeneous consistency. In this study, two distinct flavor variants were developed: cheese and bacon. At last, the finished product is transferred into sterilized glass containers and sealed airtight to preserve quality and extend shelf life.

The procedure was conducted in four replicates to produce two flavor variants by varying the raw material: conventional cashew nuts and residue-derived cashew nuts. This resulted in the formulation of cheese-flavored and bacon-flavored versions. The equipment utilized throughout the process included a Thermomix TM6, an AD3300 precision scale, a 2.6 L stainless steel mixing bowl, and a Mb 10 pH meter.

The ingredient composition of the final formulations analyzed in this study is summarized in Table 2:

Table 2 - Final product list of ingredients

	Cheese (Normal)	Cheese (Residue)	Bacon (Normal)	Bacon (Residue)
Total Mass (g)	338,55	248,09	275,79	226,50
Cashew nut residue	31,80%	31,44%	31,42%	31,35%
Potable water	63,60%	62,88%	62,85%	62,69%
Garlic powder	0,48%	0,47%	0,47%	0,47%
Bacon flavor	-	-	1,89%	1,88%
Onion powder	0,95%	0,94%	0,94%	0,94%
Citric acid	0,17%	0,23%	0,42%	0,25%
White pepper	0,34%	0,46%	0,42%	0,51%
Sweet paprika	0,00%	0,00%	1,45%	1,77%
Cheese flavor	1,48%	2,02%	-	-
Carrageenan (gum)	0,14%	0,14%	0,14%	0,14%
Salt	0,59%	0,81%	-	-
Dairy culture	0,50%	0,50%	0,50%	0,50%
Turmeric	0,44%	0,60%	-	-

Source: Author (2024)

According to Nuts *et al*. (2023), the indicators that a food item is safe for consumption include proper pH levels, compliance with hygienic handling and processing practices, absence of signs of spoilage (such as no off-odors, discoloration, slime formation, or unusual textures), and validated processing steps. These validated steps include treatments like appropriate heat pasteurization and fermentation under controlled conditions.

During the production process, heat treatment and fermentation were applied, along with standard sanitization procedures. Additionally, a pH test was conducted to assess the success of fermentation. According to Nuts *et al*. (2023), the pH should be 4.4 or lower for successful fermentation (the lower the pH, the better the fermentation outcome) in our studies all four samples had pH levels below 4.4.

Results and Discussion

A value-added product was successfully developed using byproducts from the cashew nut processing industry, specifically broken kernels and dust. The final product was stable and safe for human consumption, with a pH below 4.4.

Figure 7 illustrates the four prepared samples designated for sensory evaluation by representatives of the NGO.

The samples in Figure 7 comprise four distinct formulations, differentiated by color and raw material source. Positioned on the left side of the image, samples A and B are crafted from premium-quality cashews, while samples C and D on the right are produced using cashew residues, including broken kernels and dust. The pink-hued samples are flavored with bacon seasoning, whereas the green-tinted samples feature a cheese flavor.

Figure 7 - Cashew nut spreads produced

Source: Author (2024)

Following sample development, a degustation was conducted with representatives from Amigos do Bem, involving all four formulations. Participants did not perceive significant differences between products made from premium cashews and those incorporating cashew residue. This side-by-side sensory evaluation provided a comprehensive comparison of taste, texture, and overall quality, highlighting the potential of cashew waste as a sustainable and viable raw material to produce value-added food products.

Conclusion

This study successfully demonstrated the feasibility of producing a value-added cheese analogue at laboratory scale that is safe for human consumption. However, certain limitations were identified, highlighting the need for further research.

These include the assessment of the process viability at an industrial scale and exploration of additional applications beyond the food industry. Specifically, future studies could investigate the extraction and utilization of Cashew Nutshell Liquid (CNSL) for diverse applications, as well as valorization approaches for residues such as rotten cashews.

Moreover, optimization studies focused on improving the efficiency of the processing steps outlined in this work are warranted to enhance overall process performance.

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