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Article

Innocuity of *Mucuna*-based foods produced in Benin: assessment of L-Dopa and tannins

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Abstract: *Mucuna* seeds, once largely neglected, are gradually being incorporated into the diets of some communities in Benin because of their high protein content. However, their utilization is constrained by the presence of antinutritional compounds, particularly L-Dopa, which may pose health risks if not adequately reduced during processing. Traditional processors employ various processing methods to detoxify the seeds, but the safety of the resulting foods prepared from different *Mucuna* varieties has not been fully established. This study aimed to evaluate the L-Dopa and tannin contents of the major traditional *Mucuna*-based foods in Benin in relation to their processing methods. A total of 84 processors and consumers were interviewed to document *Mucuna* processing practices and consumption patterns. Subsequently, 10 *Mucuna*-based food samples were collected and analysed for L-Dopa using the USP–NF 2022, Issue 1 method, while total tannins were determined using the Folin–Ciocalteu method. The results showed that *Mucuna* processing and consumption were infrequent, occurring mainly once per quarter, with Ata, Afitin, and Abobo being the principal traditional products. Raw white- and black-seeded *Mucuna* contained 4.6% and 5.0% L-Dopa, respectively. Following processing, L-Dopa contents decreased markedly, ranging from 0.002% to 3.0% depending on the product. Abobo and Afitin contained residual L-Dopa levels below the 1.0% safety threshold, whereas Ata exceeded this limit. Tannin contents in processed products ranged from 0.033 to 0.841 mg tannic acid equivalents/g, indicating substantial reductions following soaking, cooking with water renewal, roasting, and fermentation. Overall, traditional processing methods effectively ensured the safety of Abobo and Afitin, whereas further optimization is required for Ata. These findings provide evidence-based guidance for improving traditional *Mucuna* processing practices and support the safe utilization of this underutilized legume to enhance dietary diversification and household food security in Benin and similar settings.

Keywords: legumes; safety; processing methods; antinutritional factors; dishes

1. Introduction

Mucuna is a fast-growing legume with significant potential for human and animal nutrition, extending beyond its application as green manure, soil erosion control, and weed management (Ezegbe *et al*., 2023; Boniface *et al*., 2024a). Owing to its adaptability to diverse agroecological conditions, high biomass production, and nitrogen-fixing capacity, *Mucuna* has become an important crop for sustainable agricultural systems, particularly in tropical and subtropical regions. In addition to its agronomic value, the seeds are recognized as a promising alternative source of plant protein for improving food and nutritional security. This legume contains essential nutrients, with a high protein content varying from 23% to 43%, comparable to that of soybean (Ayodele *et al*., 2021; Boniface *et al*., 2024b; Sowdhanya *et al*., 2024). Besides proteins, *Mucuna* seeds also contain carbohydrates, dietary fibre, lipids, minerals, vitamins, and several bioactive compounds that make them attractive for the development of functional foods and sustainable food systems. Despite these nutritional advantages, the utilization of *Mucuna* as human food remains limited because the seeds contain several chemical compounds that act as antinutritional factors. The most significant of these factors is undoubtedly L-Dopa (3,4-dihydroxy-L-phenylalanine), followed by phytic acid, trypsin inhibitors, tannins, and hydrogen cyanide (Divya *et al*., 2017; Ezegbe *et al*., 2023). These compounds form complexes with proteins, carbohydrates, and digestive enzymes, thereby interfering with digestion (Obi and Okoye, 2017; Haji, 2021; Nwajagu *et al*., 2021).

Among these antinutritional compounds, L-Dopa represents the principal food safety concern because of its relatively high concentration in *Mucuna* seeds and its potential toxicological effects when consumed in excessive amounts. Tannins also deserve particular attention because they reduce protein digestibility and decrease the bioavailability of essential minerals by forming insoluble complexes with nutrients. Consequently, ensuring the safety of *Mucuna*-based foods requires effective processing methods capable of substantially reducing these compounds while preserving the nutritional quality of the seeds. However, the concentrations of these compounds can be reduced through appropriate treatments of *Mucuna* seeds before their use in animal and human diets (Akure *et al*., 2021; Ezegbe *et al*., 2023; Sowdhanya *et al*., 2024; Zoraunye *et al*., 2025). Previous studies have shown that the L-Dopa content in *Mucuna* seeds can be reduced from 6% to 0.42%, which is safely within the recognized critical safety threshold of 1.0% for human consumption (Cassani *et al*., 2016; Nyiranshuti *et al*., 2025). Processing techniques such as dehulling, soaking, boiling, roasting, fermentation, and alkaline treatment have been reported to reduce antinutritional factors to varying degrees depending on the processing sequence, duration, and *Mucuna* variety (Ezegbe *et al*., 2023; Zoraunye *et al*., 2025). Nevertheless, the effectiveness of these traditional processing methods differs considerably among communities and food products, highlighting the need for product-specific safety assessments.

Physiologically, excessive consumption of *Mucuna* seeds leads to gastrointestinal disorders (nausea, vomiting, anorexia) and neurological effects such as paranoid delusions, hallucinations, dementia, and severe depression (Sowdhanya *et al*., 2024). Although *Mucuna* has traditionally been cultivated in Benin primarily as a cover crop for soil fertility improvement, interest in its use as human food has gradually increased because of its nutritional potential. However, its consumption remains limited, largely because processors and consumers lack adequate knowledge regarding processing methods that effectively reduce L-Dopa and other antinutritional compounds to safe levels. While numerous studies have reported the agronomic importance of cultivating *Mucuna* for soil regeneration, there is almost no study in Benin evaluating the effectiveness of traditional processing methods in reducing L-Dopa and tannin contents in locally prepared *Mucuna*-based foods. Consequently, evidence-based information on the safety of these traditional food products is insufficient, creating uncertainty regarding their suitability for regular human consumption and limiting their wider adoption in local food systems.

The present study was designed to address this important knowledge gap by evaluating the effectiveness of traditional processing methods used in Benin for reducing L-Dopa and tannin contents in different *Mucuna*-based foods prepared from different seed varieties. Specifically, the study sought to answer the following research question: How effective are the traditional processing methods used in Benin in reducing L-Dopa and tannin contents in different *Mucuna* varieties and *Mucuna*-based food products to levels considered safe for human consumption? Based on previous evidence regarding the detoxification effects of traditional processing operations, the study tested the hypothesis that traditional processing methods involving combinations of soaking, dehulling, cooking, roasting, fermentation, and alkaline treatment significantly reduce L-Dopa and tannin contents in *Mucuna*-based foods, although the degree of reduction varies among food products and seed varieties.

Accordingly, this study aimed to document the traditional processing practices and consumption patterns of *Mucuna*-based foods in selected municipalities of Benin, determine the L-Dopa and tannin contents of the major traditional *Mucuna*-based foods prepared from white- and black-seeded *Mucuna* varieties, and evaluate the effectiveness of different traditional processing methods in improving the safety of these foods for human consumption. The findings of this study provide scientific evidence to support the optimization and standardization of traditional *Mucuna* processing methods, thereby facilitating the safe utilization of this underutilized legume, promoting dietary diversification, and strengthening household food security in Benin and other regions where *Mucuna* is cultivated.

2. Materials and Methods

2.1. Ethical approval

Ethical approval was not required for this study.

2.2. Study area

The present study was conducted in six municipalities of Benin, including Kandi and Ségbana in the northern region, Savalou and Bantè in the central region, and Zakpota and Bohicon in the southern region (Figure 1). These municipalities were purposively selected because they are major *Mucuna* production areas where the seeds are traditionally processed by local communities into a variety of foods for human consumption.

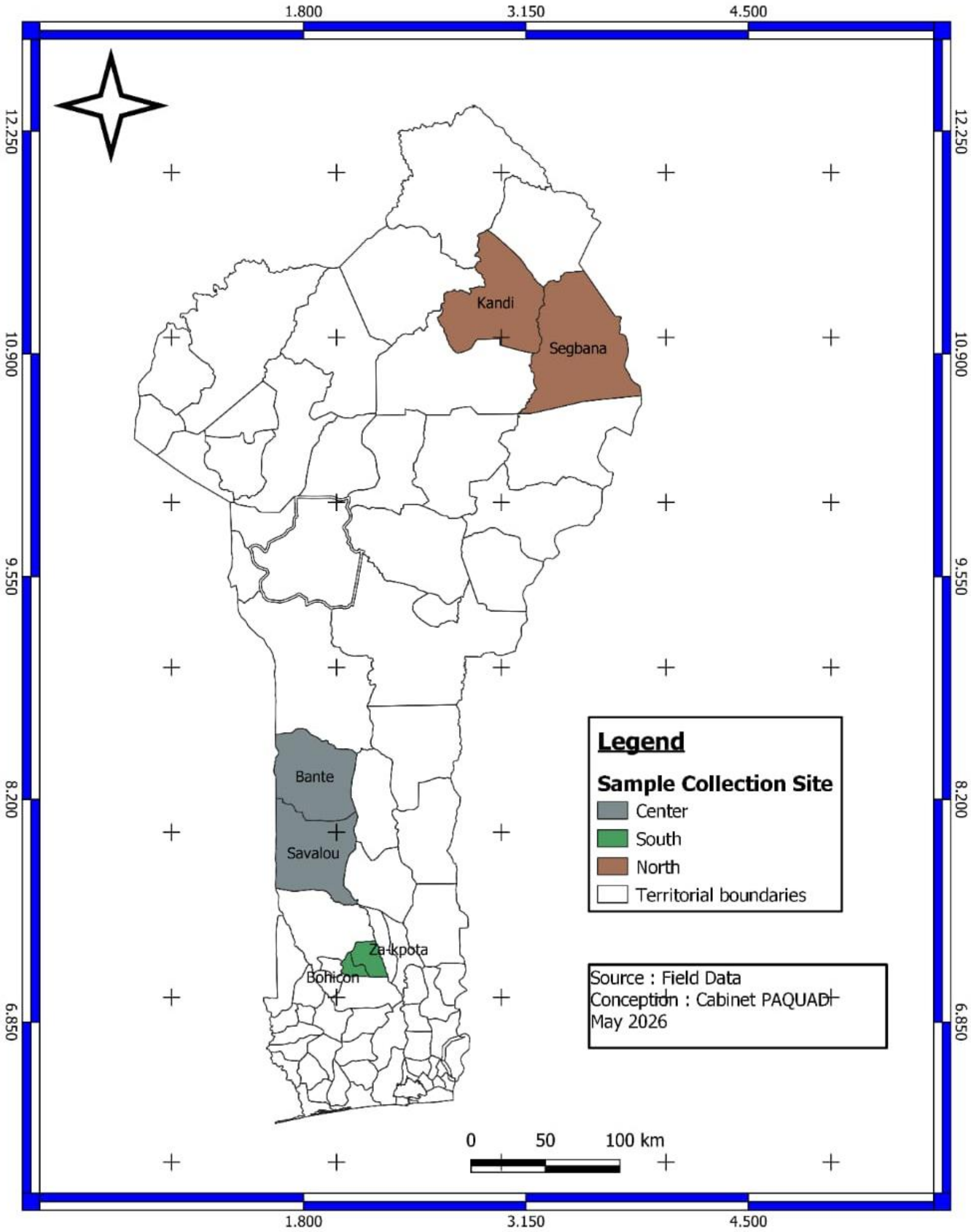

Figure 1. Different locations of *Mucuna*-based products sample collection in Benin.

2.3. Data collection and sampling of *Mucuna*-based foods

2.3.1. Diagnostic survey on *Mucuna* processing practices

A total of 84 participants, comprising 24 processors and 60 consumers, were purposively selected for this study, with 14 participants (4 processors and 10 consumers) recruited from each municipality. Individual face-to-face interviews were conducted using a semi-structured questionnaire. The questionnaire collected information on respondents' age, sex, educational level, experience in *Mucuna* processing or consumption, and the frequency of processing or consuming *Mucuna*-based products to characterize their socio-economic profile. For descriptive analysis, respondents were categorized into predefined age groups (≤20, 20–40, and 40–60 years) and experience groups (≤5, 5–10, and >10 years). In addition, data on respondents' knowledge of *Mucuna* processing methods and consumption patterns were gathered across the study area to identify the most commonly prepared and consumed *Mucuna*-based food products.

2.3.2. Sampling of foods for L-Dopa and tannin analysis

Following the diagnostic survey, samples of the most commonly consumed traditional *Mucuna*-based foods were collected for laboratory analysis. The sampled products included Afitin, Ata, and Abobo prepared either with or without potassium carbonate. For each food type, three 300-g samples were collected from three different traditional processors. The three samples were thoroughly homogenized and pooled to obtain a composite sample of approximately 500 g for analysis.
The experimental sampling design comprised four processed food types prepared from two *Mucuna* varieties (white- and black-seeded *Mucuna*), together with two raw seed samples (Figure 2). Consequently, a total of 10 samples were collected, packaged in clean polyethylene bags, and stored at −7 °C until laboratory analysis. The list of samples included in the study is presented in Table 1.

Table 1. List of samples of *Mucuna*-based foods collected for laboratory analysis.

No.	Sample code	Product description
01	Mb	Raw white *Mucuna* seeds
02	Mn	Raw black *Mucuna* seeds
03	AbMnsp	Abobo prepared from black *Mucuna* without potassium carbonate
04	AbMbsp	Abobo prepared from white *Mucuna* without potassium carbonate
05	AbMn	Abobo prepared from black *Mucuna* with potassium carbonate
06	AbMb	Abobo prepared from white *Mucuna* with potassium carbonate
07	AtMb	Ata prepared from white *Mucuna* seeds with potassium carbonate
08	AtMn	Ata prepared from black *Mucuna* seeds with potassium carbonate
09	AMn	Afitin prepared from black *Mucuna* seeds
10	Amb	Afitin prepared from white *Mucuna* seeds

Figure 2. Varieties of *Mucuna* seeds; (a) Black *Mucuna* seeds (b) White *Mucuna* seeds.

2.3.3. Samples analysis

The 10 collected samples were analyzed for L-Dopa and total tannin contents. L-Dopa determination was performed at the Chemical Laboratory of the Food and Drugs Authority (FDA), Accra, Ghana. The L-Dopa content of raw *Mucuna* seeds and *Mucuna*-based food products was determined according to the USP–NF 2022, Issue 1 analytical method.

Total tannin analysis was conducted at the Research Unit in Enzymatic and Food Engineering, Laboratory of Study and Research in Applied Chemistry, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Benin. Total tannin content was determined using the Folin–Ciocalteu method as described by Koutouan *et al*. (2019).

2.4. Statistical analysis

Data on the socio-economic characteristics of respondents were analysed using descriptive statistics, including frequencies and percentages, to summarize respondents' profiles, awareness of *Mucuna*-based products, processing practices, and consumption patterns. L-Dopa and total tannin contents were determined in triplicate for each sample, and the results are presented as mean values. Data processing and descriptive analyses were performed using Microsoft Excel 2019. The map of the study area was prepared using QGIS version 3.18.

3. Results

3.1. Socio-economic characteristics of surveyed actors

All processors were women, with 70.83% having no formal education. More than half (54.17%) were aged 40–60 years, and half (50.00%) had 5–10 years of experience in *Mucuna* seed processing. Among consumers, most (83.33%) were adults aged 20–60 years, 53.33% had less than five years of experience consuming *Mucuna*-based foods, and 66.67% had no formal education. The gender distribution among consumers was relatively balanced, comprising 53.33% males and 46.67% females. Regarding processing and consumption frequency, the majority of processors (73.33%) and consumers (78.33%) reported processing or consuming *Mucuna*-based products once per quarter, whereas only a small proportion reported doing so three times per quarter (3.34% and 5.00%, respectively) (Table 2).

Table 2. Socio-economic characteristics of *Mucuna* processors and consumers (n= 84 with 24 processors and 60 consumers).

Variables		**Processors (%)**	**Consumers (%)**
Age (year)	≤20	8.33	16.67
	20-40	37.5	43.33
	40-60	54.17	40
Sex	Male	0	53.33
	Female	100	46.67
Experience (year)	≤5	41.67	53,33
	5-10	50	40
	>10	8.33	6.67
Education level	None	70.83	66.67
	Primary	20.83	26.67
	Secondary	4.17	6.67
Frequency (time/quarter)	1	73.33	78.33
	2	23.33	16.67
	3	3.34	5

3.2. Different uses of *Mucuna* in Benin

Eight *Mucuna*-based food products were identified during the survey, including Zankpiti, Afitin, Atassi, Abobo prepared with potassium carbonate, Ata, Abobo prepared without potassium carbonate, tomato sauce enriched with *Mucuna* flour, and Moin-moin. *Mucuna* Afitin is a fermented seed condiment used to enhance the flavour of various dishes. Abobo is a dish prepared from *Mucuna* seeds and typically served with tomato sauce. Zankpiti is made from a mixture of *Mucuna* seeds, maize flour, and red palm oil, whereas Atassi consists of rice cooked with *Mucuna* seeds. Ata is a fritter prepared from *Mucuna* seed paste and fried into small patties. In addition, *Mucuna* flour is incorporated into tomato sauce to produce an enriched sauce, while Moin-moin is prepared by steaming a paste made from *Mucuna* seeds (Figure 3).

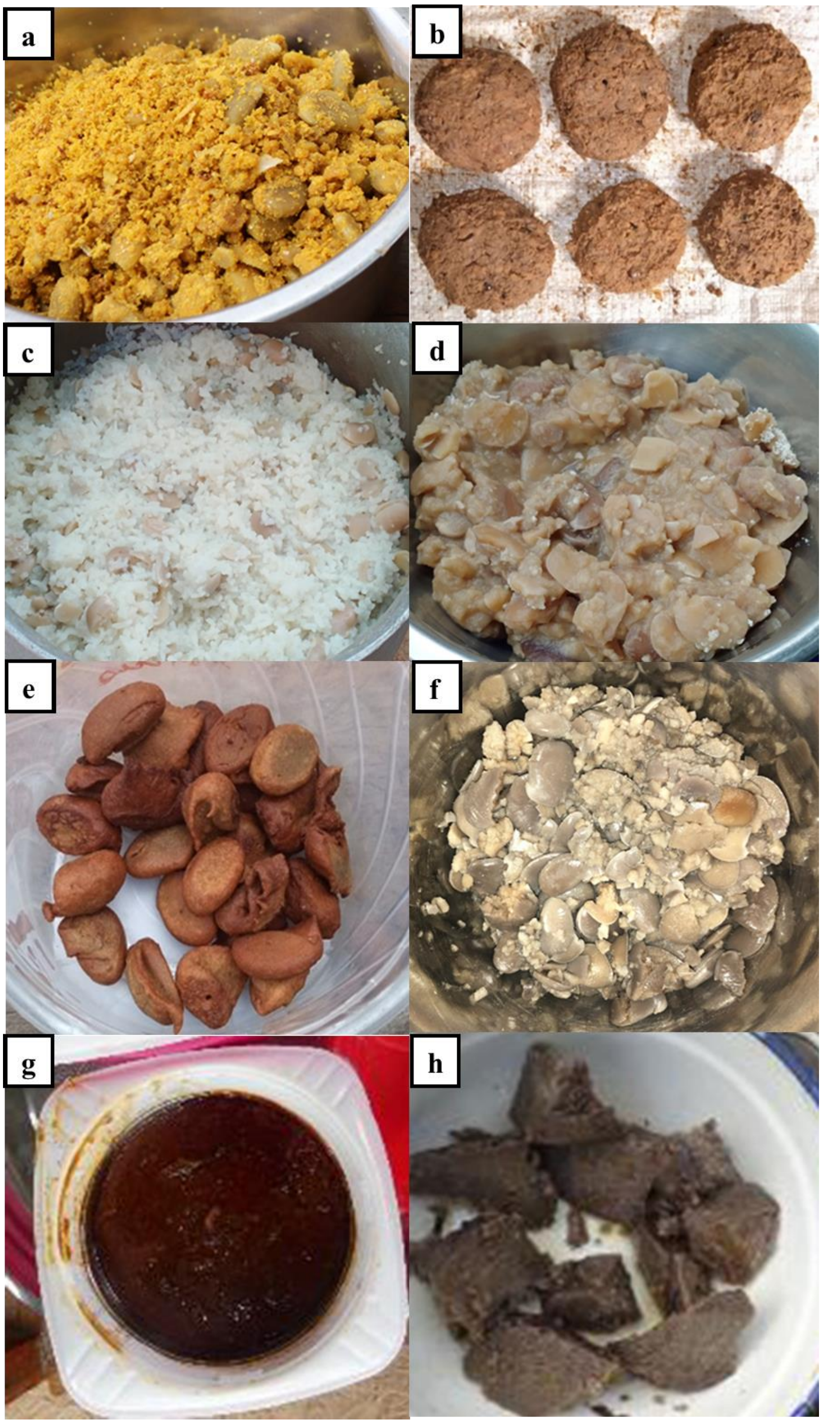

Figure 3. *Mucuna*-based products in Benin; a) *Mucuna*-based zankpiti, b) *Mucuna*-based afitin, c) *Mucuna*-based Atassi, d) Abobo prepared with potassium carbonate, e) *Mucuna*-based ata, f) Abobo prepared without potassium carbonate, g) Sauce enriched with *Mucuna* flour, and h) *Mucuna*-based moin-moin.

3.3. Diversity and awareness of *Mucuna*-based food products in Benin

Awareness of *Mucuna*-based food products varied considerably among respondents (Figure 4). Afitin, Ata, and Abobo prepared with potassium carbonate were the most widely recognized products, each known by approximately 40–45% of respondents. Abobo prepared without potassium carbonate showed a moderate level of awareness, being recognized by approximately 30–35% of respondents. In contrast, awareness of Atassi and Zankpiti was lower, with fewer than 30% of respondents reporting familiarity with these products. Moin-moin and tomato sauce enriched with *Mucuna* flour were the least recognized products, each known by less than 20% of respondents.

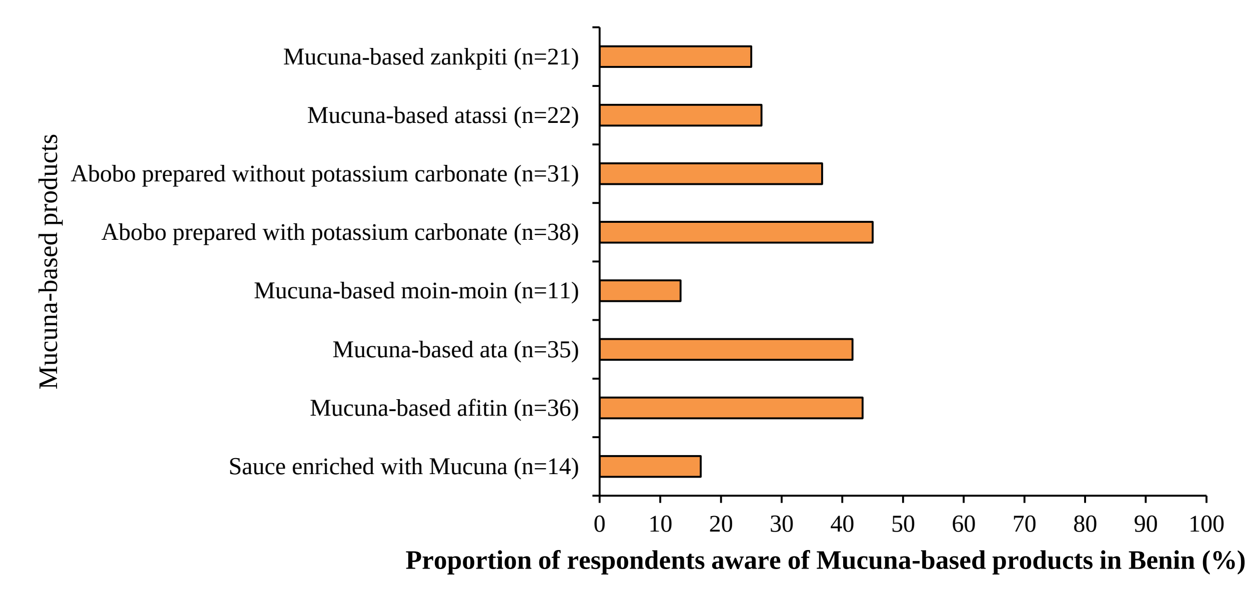

Figure 4. Awareness of traditional *Mucuna*-based food products among respondents in Benin.

3.4. Quantity of *Mucuna* seeds processed by traditional processors

The quantity of *Mucuna* seeds processed by traditional processors varied from 1.02 to 4.25 kg per quarter, indicating that fewer than 5 kg of seeds were processed per processor during this period. Among the different products, Afitin, Ata, and Abobo prepared either with or without potassium carbonate accounted for the largest quantities of *Mucuna* seeds processed, reflecting their relatively greater importance among the traditional *Mucuna*-based foods identified in the study area (Figure 5).

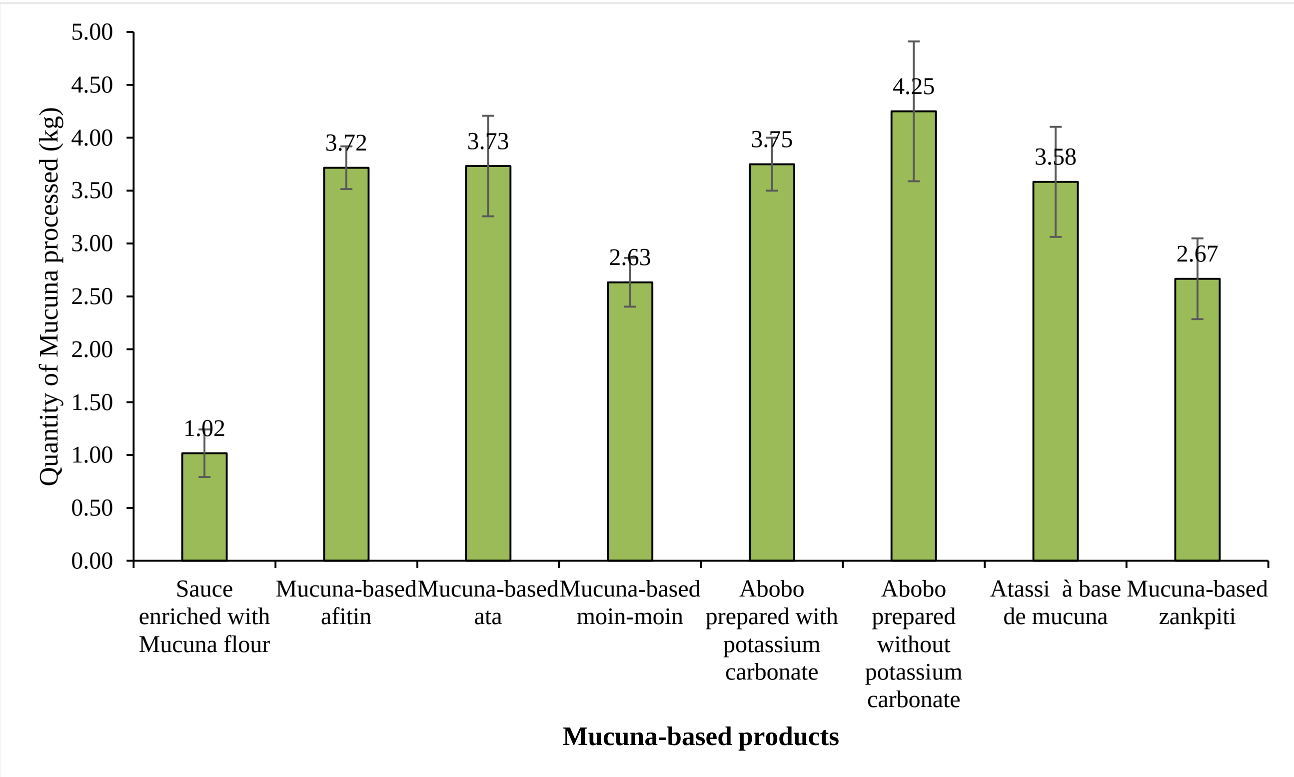

Figure 2. Quantity of *Mucuna* seeds processed by farmers per quarter.

3.5. Processing of *Mucuna* seeds into derived products

Several processing methods comprising a series of unit operations were identified among traditional women processors in the study area. Dehulling was the only operation common to all processing methods. Depending on the product, dehulling was performed either by dry milling using grinding stones to crack the seeds, as practiced in most preparations, or by wet dehulling after soaking, as applied during the preparation of Abobo without potassium carbonate.

Roasting was another important unit operation employed during processing. This thermal treatment was carried out in a pan over low to medium heat for approximately 15 min. Roasting was applied either directly to whole seeds during the preparation of Afitin or to dehulled and winnowed seeds for the production of tomato sauce enriched with *Mucuna* flour.

Soaking also constituted a major processing step, during which whole or dehulled seeds were immersed in water at room or warm temperature for 5–12 h. This operation was mainly practiced during the preparation of Abobo and Afitin (Figure 6).

Cooking was identified as another major unit operation in the processing of *Mucuna*-based foods. Depending on the product, cooking was carried out by steaming (Moin-moin), boiling in water (Abobo, tomato sauce enriched with *Mucuna* flour, Afitin, Atassi, and Zankpiti), or frying in vegetable oil (Ata). During cooking, some processors added alkaline salts, including potassium carbonate (K_2CO_3) or sodium bicarbonate, to accelerate seed softening. Renewal of the cooking water was also practiced during the preparation of Abobo without potassium carbonate and Afitin.

Fermentation was observed only during the preparation of Afitin. After cooking, the *Mucuna* seeds were spread on woven polypropylene sacks and covered with additional sacks to create anaerobic conditions conducive to fermentation for approximately 48 h, producing a fermented condiment ready for culinary use. Secondary products were also prepared from Abobo by incorporating additional ingredients; the addition of maize flour produced Zankpiti, whereas the addition of rice resulted in Atassi. Besides the major processing operations, several auxiliary steps, including sorting, winnowing, drying, draining, milling, and sieving, were incorporated into the different processing schemes to obtain the final products (Figure 6).

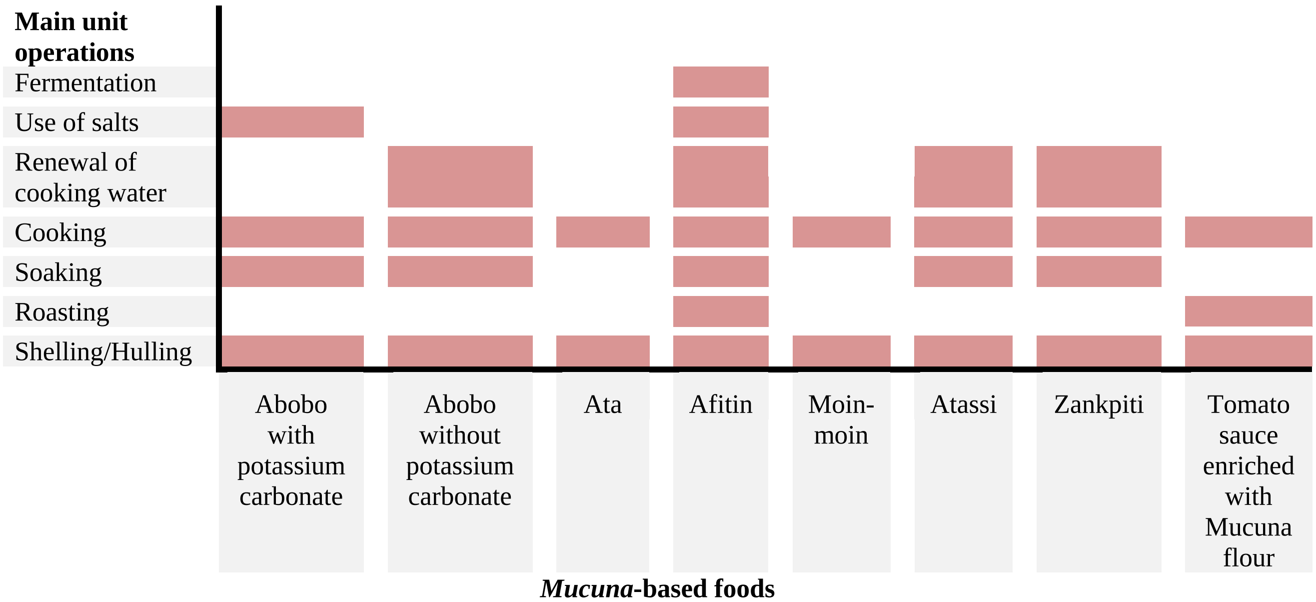

Figure 3. Unit operations involved in *Mucuna*-based foods in Benin.

3.6. L-Dopa and tannin contents of *Mucuna*-based products

Raw white- and black-seeded *Mucuna* contained 4.6% and 5.0% L-Dopa, respectively. Following processing, the L-Dopa content of the different *Mucuna*-based foods ranged from 0.002% to 3.0%. The lowest L-Dopa contents were recorded in Afitin and Abobo, whereas the highest values were observed in Ata. All Abobo and Afitin samples contained less than 1.0% L-Dopa, while Ata prepared from white- and black-seeded *Mucuna* contained 3.0% and 2.5% L-Dopa, respectively. Tannin contents also decreased markedly after processing. Raw white- and black-seeded *Mucuna* contained 1.73 and 1.87 mg tannic acid equivalents (TAE)/g of sample, respectively. Among the processed products, tannin contents ranged from 0.033 to 0.841 mg TAE/g of sample.

The lowest tannin contents were recorded in Afitin (0.033–0.038 mg TAE/g), followed by Abobo (0.079–0.335 mg TAE/g), whereas Ata exhibited the highest tannin contents (0.722–0.841 mg TAE/g) (Table 3).

Table 3. L-Dopa and tannin contents of raw *Mucuna* seeds and *Mucuna*-based derived products.

Products	L-Dopa (%)	Tannins (mg tannic acid equivalents/g of sample)
Raw white Mucuna seeds	4.6	1.73
Raw black Mucuna seeds	5	1.87
Abobo of black *Mucuna* without potassium carbonate	0.26	0.335
Abobo of white *Mucuna* without potassium carbonate	0.44	0.167
Abobo of black *Mucuna* with potassium carbonate	0.002	0.115
Abobo of white *Mucuna* with potassium carbonate	0.2	0.079
Ata of white *Mucuna*	3	0.722
Ata of black *Mucuna*	2.5	0.841
Afitin of black *Mucuna*	0.08	0.038
Afitin of white *Mucuna*	0.0029	0.033

4. Discussion

Mucuna processing in Benin is predominantly undertaken by women, reflecting the traditional gender-based division of labour commonly observed in legume processing and household food preparation. A similar pattern has been reported for cowpea processing systems in Benin, where women play a central role in processing and marketing activities (Akissoé *et al*., 2023). The finding that most processors prepare *Mucuna* only once per quarter indicates that its processing remains occasional rather than a routine household activity. Likewise, consumers, who were predominantly adults, reported limited experience with *Mucuna*-based foods and infrequent consumption, suggesting that *Mucuna* has not yet been widely incorporated into regular dietary practices. In contrast, cowpea, another important grain legume in Benin, is deeply embedded in local food systems and is consumed weekly by at least 92% of the population (Akissoé *et al*., 2022; Bodjrenou *et al*., 2025). The relatively low adoption of *Mucuna* as a food crop may be attributed to its traditional use as a cover crop for soil fertility improvement, limited awareness of safe processing techniques, and the labour-intensive nature of its preparation. Consequently, although *Mucuna* possesses considerable nutritional potential, its broader dietary integration will likely depend on increasing public awareness, improving processing technologies, and promoting safe, acceptable, and convenient *Mucuna*-based food products.

The greater awareness and higher processing frequency of Afitin, Ata, and Abobo (prepared with or without potassium carbonate) indicate that these products are the most established *Mucuna*-based foods in the study area. Their relatively higher recognition may be attributed to their similarity to traditional legume-based foods that are already familiar and widely consumed in Benin, thereby facilitating consumer acceptance. Among these products, *Mucuna* Afitin is particularly appreciated as a fermented condiment because its flavour and culinary function resemble those of condiments prepared from African locust bean (*Parkia biglobosa*) and soybean. Despite these traditional products, the diversity of *Mucuna*-based foods remains limited compared with cowpea, which has been reported to be processed into a wide range of food products in Benin (Akissoé *et al*., 2019; Akissoé *et al*., 2023). This limited product diversity likely contributes to the relatively low integration of *Mucuna* into local dietary patterns. Moreover, the small quantities of *Mucuna* processed at the household level (1.02–4.25 kg per quarter) indicate that its utilization remains largely subsistence-oriented rather than widespread. This limited processing scale may also reflect the labour-intensive nature of traditional *Mucuna* processing, particularly the multiple detoxification steps required before the seeds can be safely consumed.

The higher L-Dopa content observed in black-seeded *Mucuna* than in white-seeded *Mucuna* suggests that the accumulation of this bioactive compound is influenced by varietal characteristics. Similar observations have been reported by several authors, who found significant differences in L-Dopa concentrations among *Mucuna* varieties (Cassani *et al*., 2016; Raina and Misra, 2017; Sarmiento-Franco *et al*., 2019; Boniface *et al*., 2024a). More broadly, previous studies have reported L-Dopa contents in *Mucuna* seeds ranging from 1.04% to 13.9% (Falade *et al*., 2017; Sardjono *et al*., 2017; Sowdhanya *et al*., 2024). The wide variation among studies is likely attributable not only to genetic differences among varieties but also to environmental and agronomic factors, including soil characteristics, climatic conditions, altitude, stage of seed maturity, and crop management practices, all of which may influence the biosynthesis and accumulation of secondary metabolites such as L-Dopa.

To reduce the antinutritional factors present in raw *Mucuna* seeds, traditional processors employed a combination of processing operations. The present findings demonstrate that dehulling, soaking, cooking, roasting, fermentation, and the use of alkaline additives collectively contribute to the reduction of L-Dopa and other antinutritional compounds in *Mucuna*-based foods. Among these operations, dehulling appears to play a particularly important role because it removes the seed coat, where relatively high concentrations of L-Dopa are located. Consequently, both dry and wet dehulling, as practiced during the preparation of Abobo, Ata, and Afitin, likely contributed to the substantial reduction in L-Dopa observed in the processed products (Cassani *et al*., 2016; Olaleye *et al*., 2020). Although L-Dopa is a water-soluble compound, the soaking period applied in the present study (approximately 13 h) was shorter than the durations previously reported to maximize its removal (Diallo and Berhe, 2003). Earlier studies have shown that soaking whole seeds, even for up to 24 h, produces only limited reductions in L-Dopa because passive diffusion is restricted by the intact seed structure, thereby limiting the release of soluble compounds (Gurumoorthi *et al*., 2008). In contrast, soaking dehulled or ground seeds markedly enhances the diffusion of L-Dopa into the soaking medium. When combined with thermal or chemical treatments, particularly repeated renewal of the soaking or cooking water, this approach has been shown to reduce L-Dopa concentrations by as much as 90% (Sarmiento-Franco *et al*., 2019). These observations are consistent with the lower residual L-Dopa contents recorded in the processed *Mucuna*-based foods evaluated in the present study.

Prolonged cooking in water facilitates the leaching of water-soluble antinutritional compounds, thereby contributing to the detoxification of *Mucuna* seeds. In the present study, the processing method used for Abobo without potassium carbonate, which combines cooking of dehulled seeds with repeated renewal of the cooking water, appeared to be particularly effective in reducing residual L-Dopa. This practice likely enhances the progressive removal of soluble antinutritional compounds through the discarded cooking water. Similar observations have been reported by several authors, who recommended moist heat treatment as one of the most effective methods for processing *Mucuna* seeds intended for human and animal consumption because many antinutritional compounds are either thermolabile or readily leached into the cooking medium (Aware *et al*., 2019; Boniface *et al*., 2024b). In contrast, processing methods incorporating potassium carbonate generally do not involve renewal of the cooking water, which may reduce the extent of antinutrient removal by limiting their extraction into the cooking medium. Nevertheless, potassium carbonate accelerates seed softening and may further reduce L-Dopa through alkaline hydrolysis, thereby shortening the cooking time. However, its use has also been associated with undesirable darkening of the processed product, which may influence consumer acceptability (Sowdhanya *et al*., 2024).

Roasting is another important processing operation that contributes to the reduction of L-Dopa through thermal degradation and racemization, although it is generally less effective than soaking for the removal of tannins (Vadivel and Pugalenthi, 2008). Fermentation provides an additional detoxification effect, as fermented *Mucuna* products have consistently been reported to contain very low residual L-Dopa concentrations (<0.1%). Accordingly, the markedly lower L-Dopa contents observed in Afitin suggest that the combination of roasting, boiling, and fermentation is more effective in reducing antinutritional factors than the processing methods used for Abobo (with or without potassium carbonate) and Ata. These findings indicate that integrating multiple processing operations produces a cumulative detoxification effect, thereby enhancing the safety of *Mucuna*-based foods. Among the products analysed, Abobo and Afitin contained residual L-Dopa concentrations below 1.0%, which is the maximum level generally recommended for safe human consumption (Versteeg *et al*., 1998; Ezeagu *et al*., 2002). In contrast, Ata retained considerably higher L-Dopa concentrations (2.5–3.0%), exceeding the recommended safety threshold. This difference is likely attributable to the absence or lower intensity of some detoxification steps, particularly prolonged soaking, repeated renewal of the cooking water, and fermentation. Therefore, although Ata remains a traditional *Mucuna*-based food, optimization of its processing method is necessary before it can be considered suitable for regular human consumption. Further research should focus on refining the processing protocol to achieve greater reductions in residual L-Dopa while maintaining the product's nutritional and sensory qualities.

Although the L-Dopa contents of Abobo and Afitin were low, the maximum tolerable intake has been reported to be 1.5 g/person/day (Pugalenthi and Vadivel, 2007). Therefore, the amount of each *Mucuna*-based product that can be safely consumed depends on its residual L-Dopa concentration after processing. Lower residual L-Dopa levels permit higher levels of consumption, and products such as Afitin (prepared from both black- and white-seeded *Mucuna*) and Abobo prepared from black-seeded *Mucuna* with potassium carbonate are therefore expected to present a lower dietary risk. In contrast, excessive intake of products with elevated L-Dopa

concentrations may cause gastrointestinal disturbances, including nausea, vomiting, and anorexia, as well as neurological disorders such as hallucinations, paranoid delusions, dementia, and severe depression (Aware *et al*., 2019; Boniface *et al*., 2024a; Sowdhanya *et al*., 2024). Although these adverse effects are primarily attributed to L-Dopa, the potential contribution of other bioactive constituents present in *Mucuna* seeds cannot be excluded.
The low tannin contents observed in all analysed *Mucuna*-based products indicate that the traditional processing methods effectively reduced these compounds to levels considered safe for consumption. Tannins are water-soluble compounds predominantly concentrated in the seed coat and can be effectively reduced through conventional processing methods such as dehulling, soaking, and moist heat treatment, as well as by modern technologies, biological treatments, and combined processing strategies (Vashishth *et al*., 2024; Amarowicz and Pegg, 2024; Zayed *et al*., 2025). The tannin contents measured in the processed *Mucuna* products were well below the threshold of 10 mg/g considered potentially harmful to human health (Ojo, 2022; Abebaw *et al*., 2025). Nevertheless, excessive consumption of tannin-rich foods may impair the absorption of essential minerals, vitamins, and proteins, thereby reducing the nutritional value of the diet (Hoque *et al*., 2024; Zayed *et al*., 2025).

5. Conclusions

This study evaluated the L-Dopa and tannin contents of traditional *Mucuna*-based foods produced using different processing methods in Benin. The results demonstrated that processing techniques involving prolonged soaking of dehulled seeds, cooking with renewal of the cooking water, roasting, and fermentation substantially reduced the L-Dopa and tannin contents of *Mucuna*-based products. Among the products analysed, Abobo and Afitin exhibited residual L-Dopa contents below the recommended safety threshold, whereas Ata retained comparatively higher levels of L-Dopa, indicating that further refinement of its processing method is required. The low tannin contents observed in all processed products suggest that traditional processing practices effectively reduce this antinutritional factor to levels unlikely to pose a health concern. The findings highlight the potential of appropriate traditional processing methods to improve the safety of *Mucuna*-based foods and support the wider utilization of this underutilized legume for human consumption. The study provides scientific evidence to guide the optimization and standardization of traditional processing practices, thereby contributing to improved food safety, dietary diversification, and household food security. Future research should focus on optimizing the processing method for Ata and evaluating the nutritional quality, sensory attributes, and consumer acceptability of improved *Mucuna*-based food products.

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Data availability

All relevant data are within the manuscript.

Conflict of interest

None to declare.

Authors’ contribution

Ayihadji Paul Ferdinand Houssou: conceptualization, methodology, formal analysis, investigation, writing - original draft, writing - review and editing, visualisation, supervision, project administration; funding acquisition; Valère Dansou: investigation, data curation, formal analysis, writing - original draft, writing - review and editing; Bodéhoussè Abel Hotegni: investigation, data curation, formal analysis, writing - original draft, writing - review and editing; Hugue Zannou: investigation, data curation, formal analysis, writing - original draft, writing - review and editing; Bertrand Vigninou Gbenontin: writing - original draft, writing - review and editing; visualization; Camille Bankole: investigation, data curation, writing - original draft; Paul Fidéle Tchobo: analysis of samples - writing - review and editing. All authors have read and approved the final manuscript.

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