

RESEARCH PAPER

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Factors influencing the use of *Mucuna pruriens* as food in Benin, West Africa

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ABSTRACT

Mucuna pruriens (velvet bean) is a leguminous cover crop widely promoted in Benin for soil restoration and regeneration. This study aimed to assess the knowledge, consumption patterns, and processing methods of *Mucuna pruriens* among local communities, as well as to characterize its seed type using machine vision. Data were collected from 506 respondents across northern Benin through semi-structured questionnaires, participant observation, and snowballing sampling. Three *Mucuna* seed types were identified. Analyses of seed size, shape, and coat colour revealed significant differences among types: the black seed type exhibited larger, rounder, more compact, and darker seeds, the brown-white seed type had smaller, elongated, and lighter-yellow seeds, and dark brown seed type showed intermediate traits. Although 53% of respondents were aware of *Mucuna*, only 17% had consumed it, and 92% reported no-consumption, primarily due to lack of knowledge and perceived toxicity related to antinutritional factors. Processing methods such as soaking, dehulling, cooking, fermentation, and roasting, were applied in combination to reduce these compounds. Commonly consumed products included fermented *Mucuna* (Sonru), fritters (Ata/Kiarou), *Mucuna*-rice mixtures (Atassi/Waké), and boiled *Mucuna* (Abobo). Knowledge of processing and consumption were higher in areas that benefited from soil restoration projects, particularly in the Alibori and Borgou Departments. These findings highlight that *Mucuna pruriens* holds potential as a food and soil-improving and hence crop production. However, its adoption for human consumption remains limited by knowledge gaps and processing constraints. Developing simpler and more effective processing techniques could enhance its dietary utilization and its contribution to improved nutritional food security.

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INTRODUCTION

Mucuna pruriens (L.) DC., commonly known as velvet bean, is a leguminous climbing plant widely recognized for its multifunctional role in agriculture and nutrition. Traditionally used as a cover crop, it contributes to soil fertility, nitrogen fixation, and erosion control, making it a key component in sustainable farming systems across tropical regions (Atakoun *et al.*, 2023; Barthès *et al.*, 2004). In addition to its agronomic benefits, *Mucuna* seeds are rich in protein (24-31.44 %), essential amino acids (3-9%), and bioactive compounds (3-6.7 %), highlighting their potential as a functional food for human and animal consumption (Pathania *et al.*, 2020; Ravindran and Ravindran, 1988; Sowdhanya *et al.*, 2024).

Despite these benefits, the adoption of *Mucuna pruriens* for human consumption remains limited in many areas. This limitation is associated with the presence of antinutritional factors, particularly the L-Dopa, which can induce gastrointestinal disturbances if seeds are not well processed (Boniface *et al.*, 2024; Daffodil *et al.*, 2016). Consequently, the consumption of *Mucuna* is largely restricted to regions where appropriate processing techniques are known and practiced such as Kenya, Guinea, Nigeria and Cameroon (Diallo and Berhe, 2003; Ezegbe *et al.*, 2023b; Mang *et al.*, 2016; Mugendi *et al.*, 2010).

In Benin, several soil restoration projects (TAZCO, ProSOL) have promoted *Mucuna* cultivation across northern departments. However, limited knowledge of nutritional properties, detoxification methods, and culinary uses continues to constrain its integration into local diets. We therefore hypothesize that communities living in areas exposed to soil restoration projects exhibit higher levels of knowledge about *Mucuna pruriens*, apply more diversified and effective processing techniques, and show a greater frequency of consumption compared to communities with little or no exposure to such interventions.

Beyond sociocultural, technological, and agronomic determinants, the study also incorporates a morpho-colorimetric characterisation of *Mucuna* seeds using

digital imaging. Machine vision-based phenotyping offers an objective, reproducible approach for assessing seed morphology and colour attributes, supporting the standardization of raw material quality. Such tools enable rapid seed sorting, quality grading, and may help predict technological behaviour during processing, thereby strengthening the link between physical seed characteristics, processing performance, and consumer acceptability.

Therefore, this study aims i) to assess the knowledge, and processing methods of *Mucuna pruriens* varieties among local communities in northern Benin, ii) to characterize the morphological and colorimetric traits of *Mucuna* seed types using a machine vision system, and iii) to identify their consumption patterns, and factors limiting the use of *Mucuna* as a food resource, while proposing strategies to enhance its adoption.

MATERIALS AND METHODS

Study area

This study was conducted from 1st June to 30 July 2025 in the Republic of Benin, a West African country located between longitudes 0°40' and 3°45' E and latitudes 06°15' and 12°25' N. Benin has an estimated population of approximately 14 million inhabitants (INStaD, 2018). The Fig. 1 presents the survey area, which covered all the four departments of northern Benin (Alibori, Atacora, Borgou, and Donga). These departments were selected due to their high levels of agricultural activity and their poor soil fertility level and involvement in the promotion of *Mucuna* for soil restoration through the TAZCO and ProSOL projects.

Data collection

Sociological and technological data were collected from stakeholders involved in *Mucuna* production and consumption. A total of 506 stakeholders (361 farmers, 7 processors, 138 consumers) were surveyed. A semi-structured questionnaire digitalised with KoboCollect was administered individually to each respondent using smartphones and tablets. Stakeholders involved in the production, processing, and consumption of *Mucuna* were identified using the snowball sampling technique. To enhance the

reliability of the collected data, we also applied triangulating technique of information sources and participatory observation of production and consumption practices related to *Mucuna*.

The data collected focused on the sociodemographic characteristics of the respondents (gender, age,

literacy level, sociocultural group, religion, and professional experience), as well as practices related to *Mucuna* production, processing, and consumption. Additional information was gathered on risk factors limiting *Mucuna* consumption and on the endogenous methods used to reduce the product's antinutritional factors.

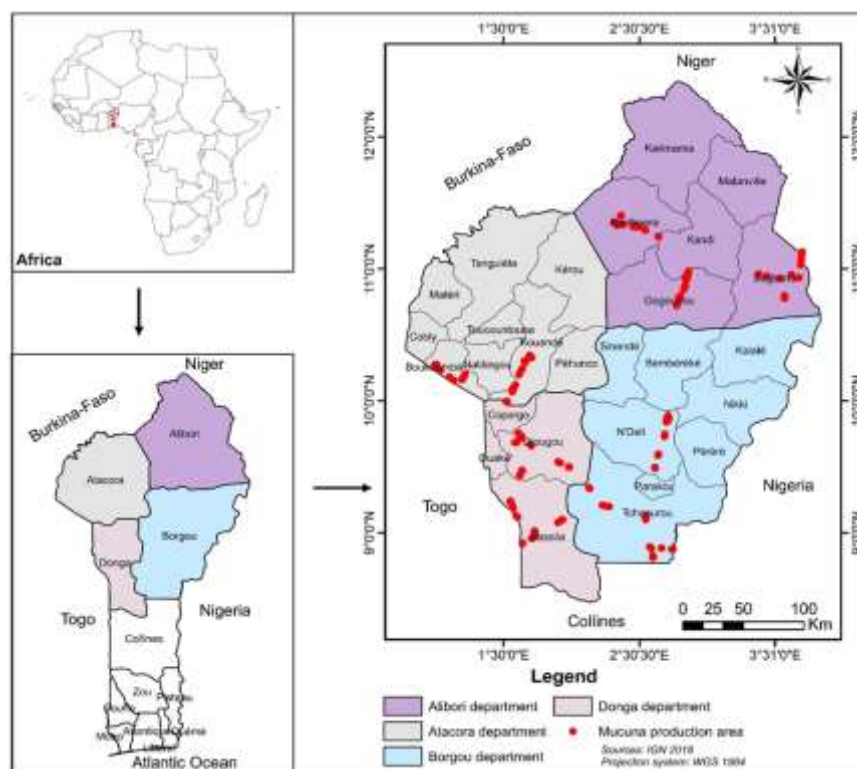


Fig. 1. Map of Northern Benin departments showing the survey area for the study

Parameters of *Mucuna* quality

Three seed types of *Mucuna pruriens* commonly used in Northern Benin (Figure 2), were sampled. All samples were collected from the Territorial Agencies for Agricultural Development (ATDA) (Table 1) for the assessment of their quality.

Digital imaging was then performed, followed by data extraction to characterize seed size, shape descriptors, and colour.

Image acquisition, replicates and sample size

One hundred of each of the three *Mucuna pruriens* seed types, three biological replicates were analysed. From each replicate, three technical replicates, consisting of three independent images captured under identical

conditions, were performed. Seeds were spread on a kaiser copy stand (400 mm × 420 mm) equipped with two Kaiser RB 128N HF lightning units.

Images were captured using a Nikon D5600 digital camera fitted with an AF-DX 18-55 mm lens, mounted on a column 55 cm above the samples. This design ensured robustness of the morphological and colour measurements.

Image segmentation and feature extraction

Seed segmentation was performed using software ImageJ in conjunction with the MICA toolbox (version 2.2.2). Initially, images were linearized and colour corrected using the X-Rite ColorChecker reference included in each capture (Trosianko and

Stevens, 2015). The segmentation process followed a standardization pipeline comprising: (1) background removal via thresholding in the L^* channel, (2) conversion to binary masks, (3) application of morphological filters for noise reduction, and (4)

contour detection to isolate individual seeds. For each identified seed, morphometric shape descriptors including length, width, perimeter, area, circularity, roundness, aspect ratio (AR), and solidity were extracted.



Fig. 2. Varieties of *Mucuna pruriens* var. *utilis* from interviewed zones

a=*Mucuna pruriens* black, b=*Mucuna pruriens* var. *cochinchinensis* brown white, c=*Mucuna pruriens* IRZ white dark brown

Table 1. Collected *Mucuna pruriens* samples used in Northern Benin

Sample codes	Seed types	Seed colour	Image codes	Collected dates	Localities (Municipality, Department)
PB	<i>Mucuna pruriens</i>	Black	a	8 June 2025	Tchaourou, Borgou
BW	<i>Mucuna pruriens</i> var. <i>cochinchinensis</i>	Brown white	b	15 July 2025	Banikoara, Alibori
DB	<i>Mucuna pruriens</i> IRZ white	Dark brown	c	28 July 2025	Segbana, Alibori

Additionally, colour metrics (L^* , a^* , b^* , C^* and h°) were calculated from the calibrated RGB images after transformation into the CIELAB colour space (Troschianko and Stevens, 2015).

The chromaticity (C^*) and hue angle (h°) were calculated from the CIELAB coordinates using the following standard equations:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

$$h^\circ = \arctan\left(\frac{a^*}{b^*}\right)$$

To avoid quadrant misinterpretation, the hue angle (h°) was computed using the two-argument arctangent function as implemented in the MICA toolbox and ImageJ colour analysis plugins.

Ethical consideration

This study was conducted in accordance with the ethical principles of the University of Parakou (UP) and followed international guidelines for research involving human participants. The full research protocol was reviewed and approved by the Ethics Committee of the University of Parakou under approval number n° 292-2025/UP/R/VR-RU/SA issued on July 17, 2025.

Data analysis

The survey data collected through the KoboCollect platform were cleaned and coded using Microsoft Excel. Prior to inferential testing, all quantitative variables were evaluated for normality and

homoscedasticity using the Shapiro-Wilk test (complemented by visual inspection of Q-Q plots) and Levene's test, respectively. For variables meeting these assumptions, a one-way ANOVA was used to assess differences among the three *Mucuna pruriens* seed types, with effect sizes. Significant ANOVA results were followed by Tukey post-hoc test for pairwise comparisons. In cases where assumptions were violated, appropriate nonparametric or robust procedures were applied: the Welch ANOVA followed by the Games-Howell post-hoc test was used when only homoscedasticity was violated, while the Kruskal-Wallis test followed by Dwass-Steel-Critchlow-Fligner (DSCF) test for significant results was used when normality test failed. The significance level was set at 5%.

Finally, correspondence analysis (CA) was conducted to explore associations between categorical variables, and all statistical analyses were performed using R software version 4.3.1 and Jamovi 2.3.28.

RESULTS AND DISCUSSION

Socio-demographic characteristics of respondents

The sociodemographic characteristics of respondents according to farmers, processors and consumers of *Mucuna* are presented in Table 2. Farmers represented the largest group (71.34%), followed by consumers (27.27%) and processors (1.38%). Gender distribution showed a predominance of men among farmers (68.14%), reflecting male dominance in agricultural activities that require physical effort while women were more represented among processors (100%). Indeed, this result showed that African women kept their traditional role in household as food preparation operators as reported by several authors (Hongbété *et al.*, 2017; Kindossi *et al.*, 2012, 2021; Madodé *et al.*, 2011).

In terms of age, 58.10% of respondents of all categories were aged between 29 to 39 years and were found across all groups: farmers (69.53%),

processors (42.86%) and consumers (32.61%). Approximately 25.49% of the total respondents aged from 18 to 28 years and most of them (80.24%) were married. In terms of educational level, most respondents either had no education (44.27%) or are literate (27.08%). This low level of formal training may partially explain the limited knowledge of improved processing methods and safety practices. Very few respondents had university level education (2.37% overall). Sociocultural group varied according to professional activity. The Bariba group were the largest percentage overall (46.25%), especially among processors (85.71%). Among the interviewed farmers, the main sociocultural groups recorded were Bariba (39.06%), Boo (14.96%), and Nago (13.57%).

Regarding religion, Islam was the dominant religion across all respondents (56.52%) followed by Christianity (40.91%) and endogenous religion (2.57%, only among farmers).

Finally in terms of experience in *Mucuna* production activity, 37.75% of all respondents had no experience, which is expected since all surveyed consumers (100%) did not produce the crop. Among farmers, most farmers had between 1-5 years of experience (44.6%) or 6-10 years (32.96%). However, about 8% had between 11-20 years of experience showing their long-standing expertise in *Mucuna* production.

Sociodemographic characteristics influenced the adoption of *Mucuna pruriens* as food/ food ingredient. Younger farmers (21.88% of respondents) and those with higher levels of education (3.05%) were more likely to cultivate *Mucuna* for both soil fertility improvement and food purposes. In contrast, older respondents (7.48%) primarily associated cropping with soil rehabilitation. Women, due to their central role in food processing, were key actors in determining household consumption, however, their limited access to training in detoxification techniques often constrained its safe use as food. Income level also

influenced consumption patterns: while low-income households appreciated *Mucuna* as an affordable legume, its long processing time discouraged frequent consumption. Overall, the

sociodemographic profile of the respondents underscores the need for targeted training and gender-sensitive extension strategies to promote the safe and acceptable food use of *Mucuna pruriens*.

Table 2. Sociodemographic characteristics of *Mucuna* study (%)

Variables	% of respondents			
	Total (n=506)	Farmers (n=361)	Processors (n=7)	Consumers (n=138)
Gender				
Male	68.18	68.14	0	71.74
Female	31.82	31.86	100	28.26
Age group (years)				
[18-28]	25.49	21.88	14.28	35.51
[29-39]	58.1	69.53	42.86	32.61
[40-50]	9.88	1.11	14.28	28.98
≥ 51	6.52	7.48	28.57	2.9
Marital status				
Married	80.24	95.57	85.71	39.86
Single	19.76	4.43	14.29	60.14
Education level				
None	44.27	54.29	42.86	18.12
Literate	27.08	32.96	14.29	12.32
Primary	8.1	6.09	28.57	12.32
Secondary	18.18	3.6	14.29	56.52
University	2.37	3.05	0	0.72
Sociocultural group				
Bariba	46.25	39.06	85.71	63.04
Otammari	12.45	11.63	0	15.22
Nago	12.06	13.57	0	8.7
Boo	11.26	14.96	14.29	1.45
Dendi	6.72	8.31	0	2.9
Anii	3.16	3.05	0	3.62
Lokpa	2.37	2.77	0	1.45
Fulfulbè	1.78	2.49	0	0
Fon	0.99	0.83	0	1.45
Yôm	0.99	0.83	0	1.45
Kotokoli	0.79	1.11	0	0
Yorouba	0.59	0.55	0	0.72
Fodoo	0.59	0.831	0	0
Religions				
Christian	40.91	40.17	42.86	42.75
Islam	56.52	56.23	57.14	57.25
Endogenous	2.57	3.6	0	0
Experience of <i>Mucuna</i> production activity (years)				
None	37.75	14.4	14.29	100
[1-5]	32.81	44.6	71.43	
[6-10]	23.72	32.96	14.29	
[11-15]	1.78	2.49	0	
[16-20]	3.95	5.54	0	

Knowledge and perceptions of *Mucuna pruriens*

The knowledge and perceptions of *Mucuna pruriens* among the 506 respondents are presented in Table 3. About 85.71% - 100% declared to have knowledge of *Mucuna*, its local cultivation, dietary use, its consumption, and the associated nutritional risk. The

chi-square test revealed a strong involvement ($p=0.003$) of processors, indicating that they have a perfect grasp of the techniques for removing antinutrients. Farmers showed moderate knowledge (47.65% - 57.62%) regarding the basic principles and cultivation of *Mucuna*, and limited knowledge (10.53% - 20%) concerning its food use, consumption

and associated risks. So, this suggests that while farmers were familiar with *Mucuna* cultivation, they were not necessarily aware of its nutritional qualities ($p > 0.05$). Consumers have the lowest knowledge (4.34%-39.85%, $p = 0.014$) confirming statistical differences, probably due to concerns about antinutrient discouraging use.

Regarding the perceptions aspects of *Mucuna*, risks rarely sway decisions (5.07% to 14.25%, across all group), but confidence in the effectiveness of processing remains low (8.86% - 13.57% of farmers believe that processing improves edibility, while only

3.62% of consumer and 100% of processors are familiar with antinutrient removal techniques), which explained its low consumption (0.72% of consumers, 100% of processors). Processors are optimistic (100% recognize the benefits and processing techniques), while farmers and consumers remain skeptical ($p = 0.001$ overall; not significant for processors at $p = 0.275$). This highlights a gap between knowledge and perception, as processors appreciate *Mucuna* for its nutritional qualities, while others avoid it for safety reasons, despite the existence of effective methods such as cooking, soaking, or autoclaving that reduce antinutrients.

Table 3. Knowledge and perception of *Mucuna pruriens*

Category	Questions	% of respondents (n=506)								
		Farmer (n=361)			Processors (n=7)			Consumers (n=138)		
		Yes	No	p-value	Yes	No	p-value	Yes	No	p-value
Knowledge	Have you ever heard about <i>Mucuna pruriens</i> ?	57.62	42.38	0.122	85.71	14.28	0.003	39.85	60.14	0.014
	Do you know about <i>Mucuna</i> ?	53.18	46.82		85.71	14.28		37.68	62.31	
	Is <i>Mucuna</i> cultivated in your locality?	47.65	52.35		100.00	0.00		39.85	60.14	
	Are you familiar with the dietary use of <i>Mucuna</i> ?	20.78	79.22		100.00	0.00		4.34	95.65	
	Have you ever consumed <i>Mucuna</i> ?	10.53	89.47		100.00	0.00		4.34	95.65	
	Have you heard about the risks associated with consuming <i>Mucuna</i> ?	13.86	86.14		57.14	42.85		11.59	88.40	
Perceptions	Do the risks influence your decision to consume this product?	7.20	92.79	0.001	14.28	85.71	0.275	5.07	94.92	0.001
	Do you think that appropriate processing processes could make <i>Mucuna</i> more edible?	13.57	86.42		100.00	0.00		11.59	88.40	
	Do you know of any techniques to eliminate the antinutritional factors of <i>Mucuna</i> ?	8.86	91.13		100.00	0.00		3.62	96.37	
	Do you consume <i>Mucuna</i> ?	9.14	90.85		100.00	0.00		0.72	99.27	

Compared to other local legumes such as cowpeas, Bambara groundnut, or soybeans, *Mucuna* is perceived as less practical and less well-known as a food product. Its superior agronomic performance contrasts with its lower culinary appeal and the complexity of its processing (Boniface *et al.*, 2024). Overall, these perceptions reveal a persistent gap between the recognized agronomic value of *Mucuna pruriens* and its underutilization as a food resource, highlighting the need for awareness campaigns and improved processing technologies.

Traditional and emerging processing techniques

Survey results revealed a wide range of processing techniques used to convert *Mucuna pruriens* into edible forms (Fig. 2). Processors claimed that the traditional method consisted of a combination of soaking, dehulling, and boiling (57.94% of respondents), followed in some cases by fermentation (11.21% of respondents),

drying (26.17% of respondents) or dry milling (26.17% of respondents), depending on the final product. Soaking times ranged from 24 to 72 hours, with multiple water changes (2-3 times), while boiling was typically prolonged to mitigate bitterness and reduce antinutrients factors. Dehulling, performed manually, was considered essential for improving both sensory quality and digestibility. The fermentation used in production of "Sonru" (2.37% of respondents) made from *Mucuna*, was common in the Borgou and Alibori departments, where knowledge of traditional transformation methods is higher. Dry milling was done to have powder to produce "Ata/Kiarou" (2.96% of respondents). Boiling was applied to *Mucuna* grains to prepare "Abobo" (9.29% of respondents) or combine with rice to produce "Atassi" (2.96% of respondents). "Abobo" (cooked beans in water) and "Atassi" (cooked mixed rice and beans) are two west African meals often made from cowpea which are also made from *Mucuna*.

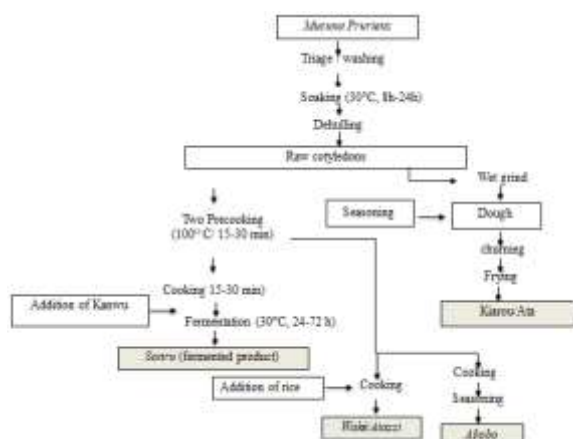


Fig. 3. Flow diagram of *Mucuna*-derived products

Respondents from Borgou (21.40%) and Alibori (36.57%) reported the greatest diversity of processing techniques and types of products, reflecting the influence of soil rehabilitation projects that have indirectly strengthened knowledge of food processing. In contrast, respondents from Donga (21.74%) and Atacora (20.53%) reported minimal processing practices, which corresponds to less exploitation of *Mucuna* cultivation and limited transfer of culinary know-how.

In contrast, households in the Donga and Atacora reported minimal or no processing practices, consistent with lower exposure to *Mucuna* cultivation and limited intergenerational transfer of culinary know-how.

Across regions, several obstacles to processing were consistently identified. The long durations of soaking and cooking steps were perceived as the main constraint, particularly in areas where access to water is very limited, especially during the dry season. Concerns about inadequate detoxification also limited consumption; those respondents expressed fears of gastrointestinal problems due to antinutritional residues.

Despite these constraints, the techniques employed are consistent with data from the scientific literature, which demonstrates their effectiveness in reducing antinutritional factors.

The combined soaking and boiling significantly decreases the levels of antinutrients, phytates, and

tannins (Akissoé *et al.*, 2022; Madodé *et al.*, 2011; Zayed *et al.*, 2025), while fermentation is used to enhance detoxification and improve aromatic profiles. The roasting and drying steps contribute to moisture reduction and product stability but require rigorous control to prevent nutrient degradation. Overall, current processing methods are effective but remain labour and resource-intensive, highlighting the need for optimized, faster, and standardized methods to facilitate their wider adoption.

Forms of dishes and culinary applications

Four main dishes were identified during the survey such as “Abobo” (Fig. 4a), “Kiarou/Ata” (Fig. 4b), “Waké/Atassi” (Fig. 4c) and “Sonru” (Fig. 4d). These dishes were derived from several forms of *Mucuna pruriens* products such as flours, fried preparations, fermented products, and legumes alone or in cereal mixtures (Fig. 4). The *Mucuna* flour was obtained after soaking, dehulling, drying, and milling. The flour is primarily used for preparing fried products named Ata in Fon or kiarou in Bariba. Sonru (fermented product) was widespread in the Borgou and Alibori departments, where traditional processing techniques were more established. Legumes alone were boiled to prepare Abobo (*Mucuna* seed boiled). Cereal and legume mixtures, such as Atassi/Waké (a mixture of rice and *Mucuna*), were less frequently consumed but remained an important option for households with limited access to animal protein.

Consumption frequency varied according to department and household socioeconomic status.

While most respondents reported occasional consumption, only a minority (1.0%) included *Mucuna* in their weekly diet. Respondents preferred fried and fermented preparations due to their superior flavour and reduced bitterness. Conversely, boiled *Mucuna* called Abobo, was less popular, primarily because of residual bitterness.

Motivations for consumption were largely nutritional and economic. Respondents (2.96%) recognized *Mucuna* as an inexpensive source of protein and a

potential alternative to cowpeas during periods of food scarcity. However, sensory concerns related to bitterness, dark colour, and strong odours limited its wider adoption. Respondents (14.62%) that had already processed *Mucuna* expressed fewer sensory concerns, suggesting that familiarity and experience played a crucial role in its acceptance.



Abobo based *Mucuna* (a)



Ata/Kiarou based *Mucuna* (b)



Waké/Atassi based *Mucuna* (Rice + *Mucuna*) (c)



Sonru (fermented *Mucuna*) (d)

Fig. 4. Forms of dishes based *Mucuna*

In Nigeria, *Mucuna* was incorporated into soups, biscuits, condiments, and thickeners, reflecting broader culinary diversification (Ezegbe *et al.*, 2023b; Onweluzo and Eilittä, 2003). In Guinea, it was used in porridges, stews, “tau” (pastes), and even roasted as a coffee

substitute (Diallo and Berhe, 2003). These experiences suggested opportunities for product innovation in Benin, particularly for *Mucuna*-based products, provided that sensory barriers were properly addressed.

Determinants of household adoption of *Mucuna* as food

The logistic regression analysis identifies several key factors influencing the adoption of *Mucuna pruriens* for human consumption (Table 4). The overall model is statistically significant (χ^2 , $p < 0.001$), with a Nagelkerke Pseudo- R^2 of 0.245. This indicates that the included variables explain approximately 24.5% of the variance in adoption behaviour.

The results show that soil restoration intervention zone (Alibori/Borgou) and professional status are primary drivers of adoption. Households located in Alibori/Borgou are significantly more likely to consume *Mucuna* than those in non-intervention zone (Atacora/Donga) (OR = 0.15, $p = 0.044$). In addition, processors display a substantially higher likelihood of adoption compared with other value chain actors (OR = 2.38, $p = 0.029$). These findings suggest that direct physical access to the crop and familiarity with its production and handling are fundamental prerequisites for its integration into the household diets. In contrast, socio-demographic factors such as sex and education level did not show statistically significant effects, indicating that adoption is not restricted to specific gender groups or social strata within the study area.

A key finding of this study is the significant interaction between the intervention zone and the diversity of food processing methods. While the number of processing methods alone shows only a marginal tendency toward significance ($p = 0.082$), its interaction with the soil restoration intervention is highly significant ($p = 0.007$). In Alibori/Borgou, mastering more than one processing method increases the odds of adoption by a factor of 3.56. This interaction indicates that the impact of culinary knowledge is context-dependent, specifically, in Alibori/Borgou departments where *Mucuna* is already available, the ability to diversify recipes acts as a powerful catalyst for its integration into household diets.

Table 4. Determinants of *Mucuna pruriens* consumption

Variable	Category	Odds Ratio (OR)	95% CI	p-value	Sig.
Actors	Processor vs. Other	2.38	[1.09 – 5.18]	0.029	*
Sex	Male vs. Female	0.82	[0.44 – 1.52]	0.528	ns
Intervention zone	Alibori/Borgou vs. Atacora/Donga	2.15	[1.02 – 4.54]	0.044	*
Processing methods	> 1 vs. ≤ 1	1.88	[0.92 – 3.84]	0.082	.
Interaction: Zone × Proc	Alibori/Borgou × (> 1 method)	3.56	[1.42 – 8.92]	0.007	**
Constant	Intercept	0.26	-	0.001	**

Table 5. Morphological and colorimetric parameters of the three varieties of *Mucuna pruriens*

Parameters	Seed type of <i>Mucuna pruriens</i>		
	BW	DB	PB
Surface area (mm ²)	144.56 ± 35.80 a	149.23 ± 31.26 a	173.03 ± 35.29 b
Perimeter (mm)	48.72 ± 9.18 a	49.05 ± 6.49 a	51.92 ± 7.78 b
Length (mm)	16.09 ± 2.28 a	16.15 ± 1.88 a	17.13 ± 2.18 b
Width (mm)	12.40 ± 1.61 a	12.68 ± 1.25 a	13.45 ± 1.30 b
Circularity	0.77 ± 0.12 a	0.78 ± 0.09 a	0.81 ± 0.08 b
AR	1.31 ± 0.15 b	1.29 ± 0.08 b	1.27 ± 0.14 a
Roundness	0.77 ± 0.06 b	0.78 ± 0.05 b	0.79 ± 0.06 a
Solidity	0.90 ± 0.07 a	0.92 ± 0.03 a	0.95 ± 0.02 b
L*	57.88 ± 3.25 c	46.67 ± 6.05 b	35.15 ± 3.21 a
a*	7.99 ± 0.74 c	7.59 ± 1.03 b	4.56 ± 1.02 a
b*	22.87 ± 1.66 c	16.56 ± 3.40 b	7.83 ± 1.97 a
C*	24.24 ± 1.59a	18.24 ± 3.43a	9.09 ± 2.07c
h°	70.68 ± 2.08a	64.98 ± 2.95b	59.40 ± 5.01b

L*= lightness index, a*= redness index, b*= yellowness index, C*= chroma, h°= hue angle, BW: *Mucuna pruriens* var. *cochinchinensis* brown white, DB: *Mucuna pruriens* IRZ White dark brown, PB: *Mucuna pruriens* black. Mean ± standard deviation; values with the same letters in the row are not significantly different at 5%.

Constraints limiting *Mucuna* food valorisation

The valorisation of *Mucuna pruriens* as food ingredient remained limited by a series of constraints, including lack of knowledge, nutritional, sensory, and technical limitations, which directly influence its adoption by households. A major obstacle was the lack of awareness of *Mucuna* (54.35% of respondents were unaware of edible food for human).

Furthermore, some respondents (17.59%) fear that *Mucuna* was toxic due to the presence of antinutritional factors, particularly the L-Dopa, whose potential toxicity was a cause for concern among consumers. Despite evidence that combined processing methods (soaking, dehulling, prolonged cooking, and fermentation) could significantly reduce these compounds, the fear of adverse effects such as gastrointestinal discomfort persisted in the communities with limited technical knowledge. These perceptions contributed to low adoption rates, even in departments where the crop was widely cultivated.

Sensory attributes also limited consumption. Many consumers cited bitterness and dark coloration as undesirable characteristics (14.62% of respondents) especially when compared to other familiar legumes such as cowpea (*Vigna unguiculata*) and Bambara groundnut (*Vigna subterranea*). These sensory limitations reduced *Mucuna*'s acceptance by children and adults unfamiliar with *Mucuna*-based foods, thus limiting its integration into the daily diet.

Technical difficulties significantly hindered the development of this food. Processing *Mucuna* requires long cooking times (57.94% of respondents), repeated water changes (26.17% of respondents), and a significant quantity of fuel (10.47% of respondents). These constraints were particularly problematic for low-income or resource-limited households. The labour-intensive process of dehulling, fermentation, and multiple soakings steps discouraged regular preparation. In departments facing water scarcity, especially during the dry season, or high firewood prices, these technical obstacles were even more pronounced.

Characterization of *Mucuna pruriens* varieties using machine vision

Table 5 presents morphological (size and shape) and colorimetric parameters of the three *Mucuna pruriens* seed types surveyed. Three seed types were characterized: *Mucuna pruriens* black (PB), *Mucuna pruriens* var. *cochinchinensis* brown-white (BW) and *Mucuna pruriens* var. *cochinchinensis* dark brown (DB). Regarding morphological parameters, for the size dominance the PB seed type was significantly larger, exhibiting the highest surface area ($173.03 \pm 35.29 \text{ mm}^2$), perimeter ($51.92 \pm 7.78 \text{ mm}$), length ($17.13 \pm 2.18 \text{ mm}$) and width ($13.45 \pm 1.30 \text{ mm}$). This suggests a greater allocation of biomass to the seed, which was often correlated with greater seedling vigor. For the shape characteristics, it is interesting to note that PB seed type exhibited the highest circularity (0.81) and solidity (0.95), indicating a more compact, smooth and structurally filled seed compared to the more elongated or irregular profiles of PB and BW seed types. No significant differences were observed between brown-white and dark brown seed type for size related traits.

The colorimetric evaluation in the CIELAB space revealed significant differences ($p < 0.05$) in seed colour among the three seed types. Lightness (L^*) was significantly higher in (BW) seed type (57.88) than in DB (46.67) and PB seed types (35.15), indicating that BW seeds were the lightest and PB seeds the darkest. The darker pigmentation of PB seed type is probably due to higher concentrations of phenolic compounds or L-Dopa in the seed coat.

Chromaticity values (redness a^* and yellowness b^*) were also significantly higher in the BW seed type ($a^* = 7.99$ and $b^* = 22.87$) than in the DB ($a^* = 7.59$ and $b^* = 16.56$) and BB seed types ($a^* = 4.56$ and $b^* = 7.83$), showing clear differences in seed pigmentation. These results confirm that BW seeds display a lighter and more yellowish coloration, whereas BB seeds exhibit a darker hue with low red and yellow intensities. The DB seed type presented intermediate chromatic characteristics.

Association between departments and uses of *Mucuna pruriens*

The correspondence analysis showed a clear association between geographical location and the reported uses of *Mucuna pruriens* (Fig. 5). The first two dimensions accounted for 89.58% of the total inertia, with Dimension 1 explaining 67.32% and Dimension 2 explaining 22.26%. Alibori was positioned close to green manure, soil fertilization, human nutrition, and animal feeding, indicating that respondents from this department reported relatively diversified uses of *Mucuna*. Borgou was clearly separated from the other departments and was strongly associated with soil regeneration. In contrast, Atacora and Donga were located close to the “None” category, indicating little or no reported utilization of *Mucuna*. Overall, the analysis revealed marked geographical differences in *Mucuna* utilization, with Alibori and Borgou being associated with specific agronomic and nutritional uses, whereas limited utilization characterized Atacora and Donga.

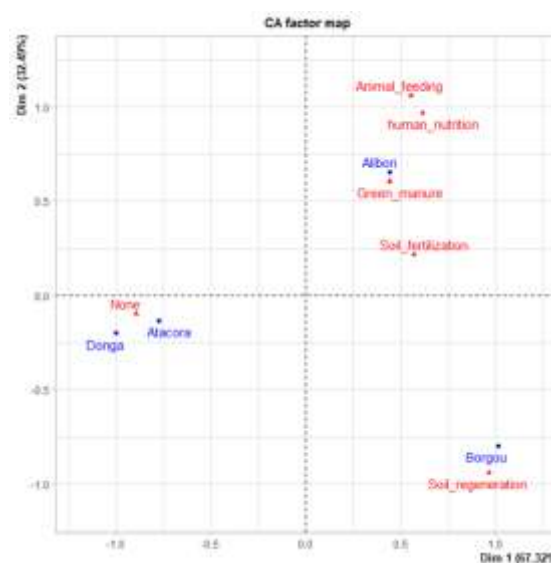


Fig. 5. Correlation between departments and uses of *Mucuna pruriens*

Association between actor categories and *Mucuna*-based dishes

The correspondence analysis of *Mucuna*-based dishes according to categories of interviewed actors showed that the first two dimensions explained the entire variation represented in the analysis, with Dimension

1 accounting for 82.3% and Dimension 2 for 17.7% (Fig. 6). Processors were clearly separated from farmers and consumers and were most closely associated with Sonru/Afitin, indicating the importance of processors in the preparation of fermented *Mucuna*-based products. Farmers were positioned close to Abobo and the “Nothing” category. Consumers occupied an intermediate position and were more closely oriented toward Kiaru and Atassi than toward Sonru/Afitin. Thus, the distribution of dishes differed according to the category of actors, with processors particularly associated with fermented products, while other *Mucuna*-based dishes were more closely related to farmers and consumers.

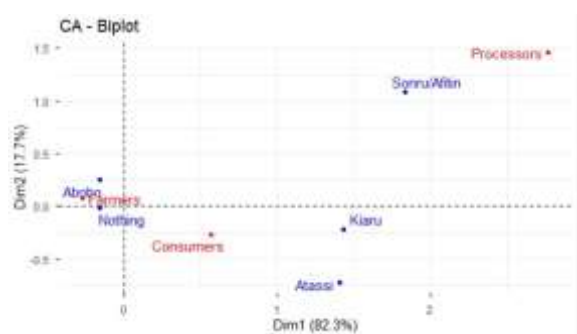


Fig. 6. Dishes based *Mucuna* identified by category of actors interviewed

Association between sociocultural groups and uses of *Mucuna pruriens*

The correspondence analysis further revealed differences in the uses of *Mucuna pruriens* among sociocultural groups (Fig. 7). Dimensions 1 and 2 accounted for 67.29% and 21.59% of the total inertia, respectively, representing 88.88% of the variation. Boo was positioned closest to human nutrition, suggesting a comparatively strong association of this sociocultural group with the dietary use of *Mucuna*. Yoruba and Fulfulbé were located in the same general quadrant as human nutrition and animal feeding, while green manure was also positioned on the positive side of Dimension 1. Bariba was situated near soil fertilization, indicating an association with this agronomic use. Fon and Nago were positioned toward soil regeneration, whereas Kotokoli, Foodo, Yom, Dendi, Otammari, and Lokpa were located on the

opposite side of Dimension 1 and generally away from the major reported uses. The “None” category was comparatively close to Otammari and Lokpa. These results demonstrate that the utilization of *Mucuna* varied among sociocultural groups, ranging from food and animal-feed uses to soil fertility and regeneration functions.

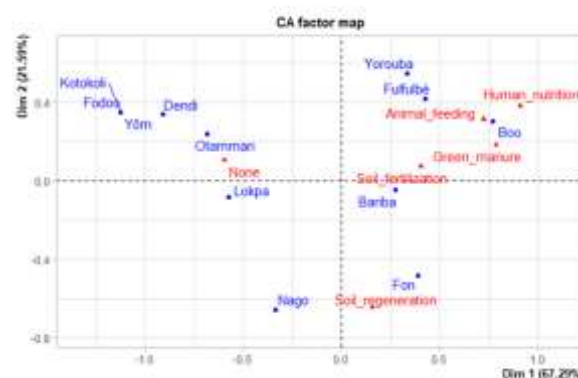


Fig. 7. Correspondence analysis to reveal linkages between sociocultural groups and uses of *Mucuna pruriens*

Mucuna pruriens, (velvet bean) is widely recognized in rural areas of Benin, primarily due to its promotion through soil restoration and regeneration initiatives such as ProSOL and TAZCO. In recent years, its cultivation has expanded in response to increasing climate variability, soil degradation and declining soil productivity. As agricultural yields decreased and soil fertility deteriorated, farmers increasingly adopted *Mucuna* as a sustainable option to restore soil function and productivity.

The availability of *Mucuna* is closely associated with its agronomic promotion for soil fertilization, as reported by 46.45% of respondents. This explains its widespread presence, in the Borgou and Alibori departments, while its absence in Donga and Atacora reflects limited exposure to soil restoration interventions. In addition, *Mucuna* is valued for its high biomass production and tolerance to poor soils, characteristics that distinguish it from other legumes and indirectly encourage its consideration for food use. However, in areas where *Mucuna* is primarily cultivated for soil rehabilitation, its use for human

consumption (7.11% of respondents) and animal feed (11.1% of respondents) remained low, indicating that agronomic availability alone does not translate into dietary adoption.

Socioeconomic constraints further limit the integration of *Mucuna* into household diets. Limited market access and the absence of organized value chains reduce incentives for processing and commercialisation. Although, *Mucuna* seeds are inexpensive (around €0.50 per kilogram) and often locally available, its labour intensive and time-consuming processing discourages use, particularly among households with limited labour capacity.

Consequently, while *Mucuna* represents a potentially affordable protein source for low-income households, this potential is realized only where processing knowledge is well established. The lack of readily-to-use or commercialized *Mucuna*-based products further limits its adoption. Cultural factors also influence consumption patterns across sociocultural groups.

Sociocultural groups with strong culinary traditions, such as Bariba, Fulani, Boo, Yoruba, and Fon, demonstrate greater familiarity with *Mucuna* based dishes, including fermented product (Sonru), fried products (Ata), and cereals-*Mucuna* mixtures (Atassi). In contrast, households in Donga and Atacora departments rarely consume *Mucuna*, reflecting limited exposure as well as persistent perception of toxicity or unsuitability for human consumption. Local food taboos associated with dark-coloured foods and crops traditionally linked to animal feed further contribute to consumer reluctance.

Gender plays a central role in the adoption of *Mucuna*. Women, who accounted for 31.82% of respondents, are primarily responsible for food processing, meal preparation, and household dietary choices. Their perceptions of the labour requirements, food safety, and sensory quality strongly influence the integration of *Mucuna* into daily meals. In areas where women had access to

training or demonstrations on processing methods, consumption of *Mucuna* was more frequently reported, highlighting the importance of targeted capacity building initiatives.

Three seed types of *Mucuna pruriens* were identified in Benin: *Mucuna pruriens* black (PB), *Mucuna pruriens* var. *cochinchinensis* brown-white (BW) and *Mucuna pruriens* IRZ White dark brown (DB). Morphological analyses revealed significant variation in seed size, shape, and colour. The PB type exhibited greater seed length, width, surface area, rounder, and a more compact morphology, along with a darker seed coat, forming a distinct phenotypic group. In contrast, the BW and DB types were morphologically similar but differed clearly in colorimetric profiles. The L^* , a^* , and b^* values indicate that seed coat pigmentation is a reliable phenotypic marker for distinguishing these seed types. Specifically, the higher lightness (L^*) and yellowness (b^*) values observed in BW seeds contrast with the darker, melanized profile of PB seeds, supporting their use in automated sorting and processing applications (Abtahi *et al.*, 2022).

Differences in colour parameters further influence consumer perception. BW seeds exhibited higher chroma (C^*) values indicating brighter and more saturated coloration, which may enhance visual appeal in local markets where appearance strongly influences purchasing decisions. Variations in hue angle (h°) among seed type suggest that PB seeds have a less yellowish tone, which may affect both consumer acceptance and the colour of processed products (Sowdhanya *et al.*, 2024).

Overall, this study demonstrates that *Mucuna* is used not only for soil fertility improvement but also in animal and human nutrition (Sowdhanya *et al.*, 2024). However, human consumption remains limited, largely because early soil restoration programs promoted *Mucuna* primarily for agronomic purposes rather than as a food crop. In addition, limited knowledge of appropriate processing methods and concerns about antinutritional factors, notably

the L-Dopa, contribute to consumer reluctance. Boniface *et al.* (2024) demonstrated that consumption of inadequately processed *Mucuna* seeds can cause gastrointestinal disorders and other harmful side effects due to high L-Dopa levels. In Benin, the main health risks associated with *Mucuna* consumption include diarrhoea and vomiting. These risks can be substantially reduced through appropriate processing techniques such as soaking, dehulling, and cooking. Combined soaking and thermal treatments have been shown to effectively reduce antinutritional factors while maintaining protein digestibility (Mugendi *et al.*, 2010). When adequately processed, *Mucuna pruriens* can serve as functional and therapeutic foods (Maillot *et al.*, 2022).

Several *Mucuna*-based food products were identified in Benin, including fermented *Mucuna* (Sonru), fritters (Ata/Kiarou), a cereal-*Mucuna* mixture (Atassi, Waké), and boiled *Mucuna* (Abobo), particularly in Alibori and Borgou, where soil restoration interventions were most extensive. Comparable uses have been in Nigeria, where *Mucuna* is incorporated into soups, thickeners, biscuits, flours, and condiments (Ene-Obong and Carnovale, 1992; Ezegbe *et al.*, 2023a), and in Guinea, where it is consumed in stews, porridge (tau paste), and as a coffee substitute (Diallo and Berhe, 2003). Despite its nutritional and functional potential, processing *Mucuna* for human consumption remains labour-intensive. Further research is therefore needed to develop simplified, efficient, and culturally acceptable processing methods to enhance adoption.

Growing interest in nutrient-rich traditional foods presents opportunities for the development of *Mucuna*-based products such as instant flours, fortified blends, and snack foods. These products could contribute to food security in northern Benin by promoting locally available protein sources while, supporting small-scale processing enterprises, and local value addition.

Integrating *Mucuna*-based foods into school feeding programs could further improve dietary quality. Promoting *Mucuna* as a food resource may therefore

strengthen the relation between soil fertility management and sustainable food systems.

CONCLUSION

This study provides an integrated assessment of the agronomic, sociocultural, and technological dimensions shaping the use of *Mucuna pruriens* in northern Benin. Using household surveys and machine vision analysis, three seed types such as brown-white, dark brown, and black, were identified each exhibiting distinct morphological and colour characteristics. The PB seed type formed a clearly differentiated group, characterized by larger, rounder, more compact, and with a darker seed coat, highlighting the potential value of phenotypic classification for processing and value-chain development.

Although *Mucuna* is widely cultivated for soil restoration, its contribution to human nutrition remains limited. This limited adoption is primarily associated with insufficient awareness of its food potential, concerns regarding toxicity linked to antinutritional factors (notably L-Dopa), and inadequate knowledge of appropriate processing methods. However, this study confirms that combined processing methods such as soaking, dehulling, and cooking, can effectively reduce antinutritional compounds and enable the safe preparation of various *Mucuna*-based foods including fermented products, fritters, cereal-*Mucuna* mixtures, and boiled seed.

From a food security perspective, the findings indicate that increasing *Mucuna* consumption requires more than general awareness campaigns or formal education. Instead, targeted interventions that link crop availability with processing skills particularly within production hubs are likely to be more effective. Strengthening local processing knowledge, especially among women who play a central role in household food decisions, is critical for enhancing adoption.

Overall, *Mucuna pruriens* holds substantial potential as both a soil-improving crop and a

locally available protein source. By bridging agronomic interventions with food-oriented processing innovation, *Mucuna* could contribute meaningfully to diversified diets, improved nutrition, and resilient food systems in northern Benin. Integrating *Mucuna*-based foods into local markets and institutional feeding programs may further enhance its role in strengthening household and regional food security.

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