

Effect of processing on physicochemical and nutritional quality of Toubani, a traditional steamed cowpea-based moistpaste from West Africa

Abstract

Toubani is a traditional cowpea-based dish, that has significant place in the culinary traditions of sub-Saharan Africa. Our study aimed to elucidate the nuanced nutritional and physicochemical profiles of distinct Toubani variants, reflecting the preferences and practices of the Beninese population. We collected 40 samples across five cities for comprehensive analysis. Regarding physicochemical characteristics, the Toubani made from hulled cowpeas exhibited heightened acidity and lower levels of dry matter, contrasting with the Toubani made from unhulled cowpeas plus yam and fermented Toubani made from unhulled cowpeas plus yam, which displayed significantly elevated values ($p < 0.05$). On the nutritional front, the fermented Toubani stood out with higher content of carbohydrates and caloric density. In contrast, the Toubani made from hulled cowpeas and the Toubani made from unhulled cowpeas variants exhibited notably lower values ($p < 0.05$) while boasting substantial protein content. Additionally, we observed an interdependence of approximately 74 % between the assessed parameters and the production processes

Key words: cowpea, Toubani, nutritional profile, physico-chemical characteristics.

Practical Application

This research on Toubani, a traditional cowpea-based dish, could lead to improved production methods that enhance its nutritional quality, potentially offering a nutritious and culturally significant food option for consumers in West Africa and beyond. By understanding the physicochemical and nutritional nuances of Toubani variants, food producers may be able to develop standardized methods that ensure consistency and quality, contributing to sustainable and health-conscious dietary practices.

Introduction

Cowpea [*Vigna unguiculata* (L.) Walp.] is a legume widely cultivated and consumed in sub-Saharan African countries. It is a staple in both rural and urban settings, with varying forms of consumption (Kebede & Bekeko, 2020). In Benin, a West African country, the frequency of consuming cowpea-based dishes was approximately seven times per week in urban and rural areas, respectively (Akissoé *et al.*, 2019). Cowpea consumption in Benin is estimated to be several tons per year (Kebede & Bekeko, 2020; Madodé *et al.*, 2012). Production and consumption patterns depend not only on agro-ecological zones but also on the dietary habits of the population.

Numerous cowpea varieties with diverse technological, culinary, nutritional, and organoleptic properties exist (Madodé *et al.*, 2011). This diversity has led to the development of various

preservation techniques and forms of cowpea consumption. In the northern part of Benin, cowpea is typically consumed in the form of a steamed paste, commonly known as Toubani in Dendi and Bariba socio cultural groups (Bio Nikki Sarè *et al.*, 2023; Hongbété *et al.*, 2017). Toubani is traditionally prepared by steam-cooking a cowpea paste or a mixture of cowpea flour and yam peel flour. It is commonly consumed with vegetable oil, chili powder, and onion slices, representing a highly energy-dense cake frequently enjoyed for breakfast and lunch by a significant portion of the population (Hongbété *et al.*, 2017).

This culinary tradition extends beyond Benin and is found in other West African countries such as Nigeria, Burkina Faso, Niger, Togo, Côte d'Ivoire, and even in certain regions of the Americas, like Brazil, where it goes by various names such as Toubani, Tibani, Tchimani, Tchimbani, Toumbani, Moin-moin, Moyi-moyi, Magni-magni, etc. (Cardoso *et al.*, 2021; Otunola & Afolayan, 2018). In these countries, including Benin, the people involved in the production and sale of this food are primarily illiterate, despite its consumption across all social classes. Furthermore, there is limited documentation on the production technology of these Toubani types in these countries due to the endogenous nature of the product. While some authors, such as Akissoé *et al.* (2019), Akisoe (2021) and Madodé *et al.* (2011), have studied different types of cowpea-based pastries and fried products, exploring their technological, sensory, and nutritional aspects, Toubani has been overlooked despite being a prominent legume-based food.

According to these authors, the distinctions between these legume-based foods are influenced by proportions of raw materials and ingredients used, production technologies based on the dehulling or non-dehulling of cowpea grains, fermentation or non-fermentation of the mixture of cowpea and yam flour, and the use of potash. However, several challenges during the preparation of legume-based foods have been researched by these authors. The laborious nature of certain unit operations and the lack of suitable equipment to facilitate these unit operations are the main causes (Akisoe, 2021). The lack of academic qualifications among those involved in the production and commercialization of Toubani, coupled with the endogenous nature of the manufacturing process, explains the non-adherence to good production practices and the non-standardization of the production process. These factors contribute to the production of multiple Toubani variants with unknown physicochemical and nutritional characteristics.

Therefore, the availability of numerous Toubani variants does not provide consumers with insights into the quality components of this product. Research on determining the

physicochemical profile and nutritional composition of each Toubani variant, given its widespread consumption, would be beneficial for better characterization, improvement, and positioning among the most consumed foods in West Africa. This study aims to determine the physicochemical characteristics and nutritional quality of different Toubani variants consumed in Benin.

2. Materials and methods

Study area

This research was carried out in the northern region of Benin, specifically in urban settings within the major cities of the Borgou, Alibori, and Donga departments. These cities, including Parakou, Nikki, Kandi, Malanville, and Djougou, were chosen as they serve as municipal and, in most cases, departmental capitals. The selection of these cities was based on their shared sociocultural characteristics and their significance as hubs for both the production and consumption of Toubani. The map below provides a visual representation of the geographical positioning of the study area.

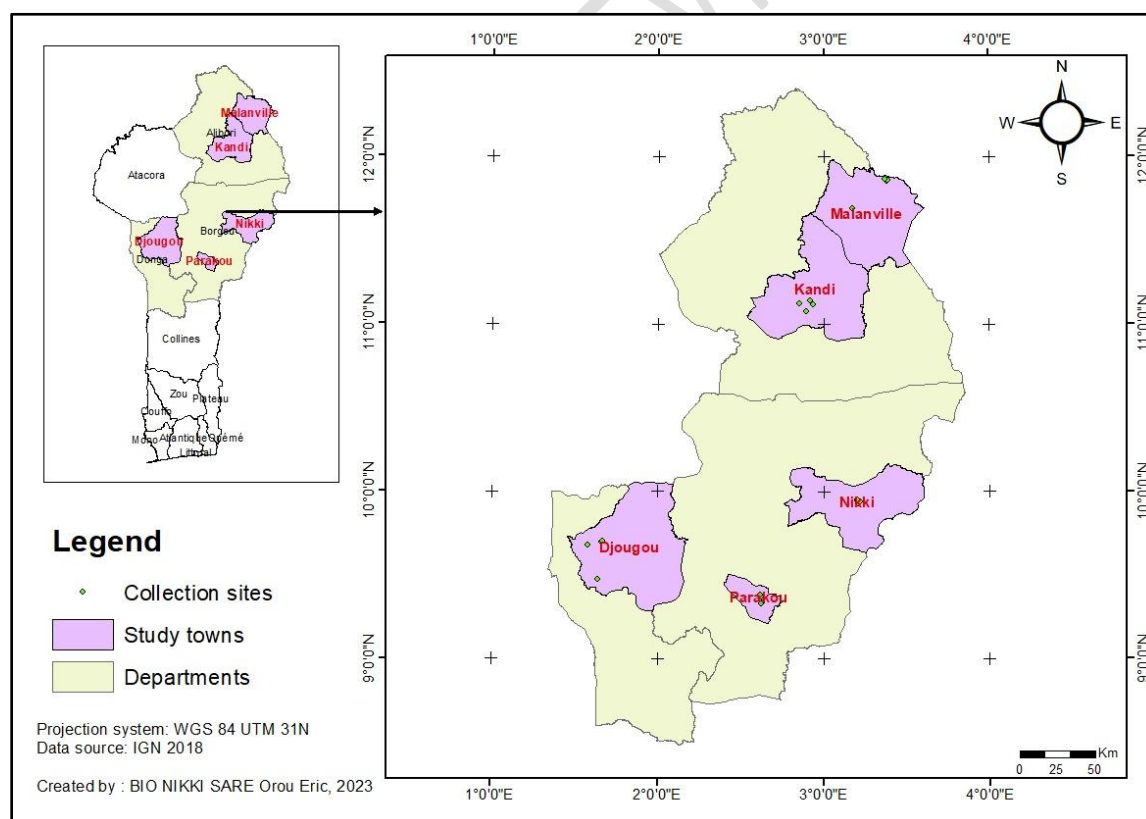


Figure 1 : Map of the study area.

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88 **Study methods**

89 ***Sampling***

90 A preliminary survey and interviews were conducted before the actual sampling, engaging
91 with Toubani producers-sellers at their selling locations to facilitate the selection of Toubani
92 types, taking into account the various Toubani variants. The Toubani variants were identified
93 using the method proposed by Bio Nikki Sarè *et al.* (2023). Four Toubani variants were
94 considered. Two samples for each of the four Toubani variants were collected in each city
95 from Toubani producers at their selling locations, totaling 40 samples. Sampling was
96 conducted from the identified top-performing producers during the preliminary survey.
97 Portions of 200g from each sample type were collected. Each sampled item was carefully
98 labeled, coded, and placed in an insulated container before being transported directly to the
99 laboratory for analysis.

100 ***Descriptions of Techniques for Producing Toubani Variants***

101 Following the investigation conducted by Bio Nikki Sarè *et al.* (2023), Toubani is
102 produced using cowpea grains from the *Vigna unguiculata* cultivar. During production, the
103 grains are carefully sorted and winnowed to obtain clean grains, which are then crushed and
104 ground. The resulting flour is mixed with water, potash solution, and salt in a random order
105 and proportions determined by the producer. The mixture is thoroughly kneaded to achieve a
106 homogeneous and smooth dough. This dough is then packaged in recycled plastic or metal
107 containers lined with a film before undergoing steaming in ordinary pots and pans at
108 temperatures between 120 and 145°C for 30 to 60 minutes (Variant 1: TND).

109 Some producers, during the mixing process, substitute flours by adding approximately
110 20 to 40% yam peel flour to cowpea flour before proceeding with the other steps of the
111 process (Variant 2: TND+I). Others allow the mixture to ferment for 5 to 8 hours just before
112 cooking, using biological yeast such as *Saccharomyces cerevisiae* to achieve lighter products
113 (Variant 3: TFND+I). However, a minority of producers prefer soaking the initially sorted and
114 winnowed cowpea grains for 2 to 5 hours to achieve dehulling. The dehulled grains are then
115 ground to obtain a paste, which is mixed with water, potash solution, and salt before thorough
116 kneading and steaming (Variant 4: TD). This process results in white Toubani.

It is worth noting that all encountered variants of Toubani are consumed accompanied by a cold sauce consisting of vegetable oil, salt, chili powder, and freshly sliced onions.

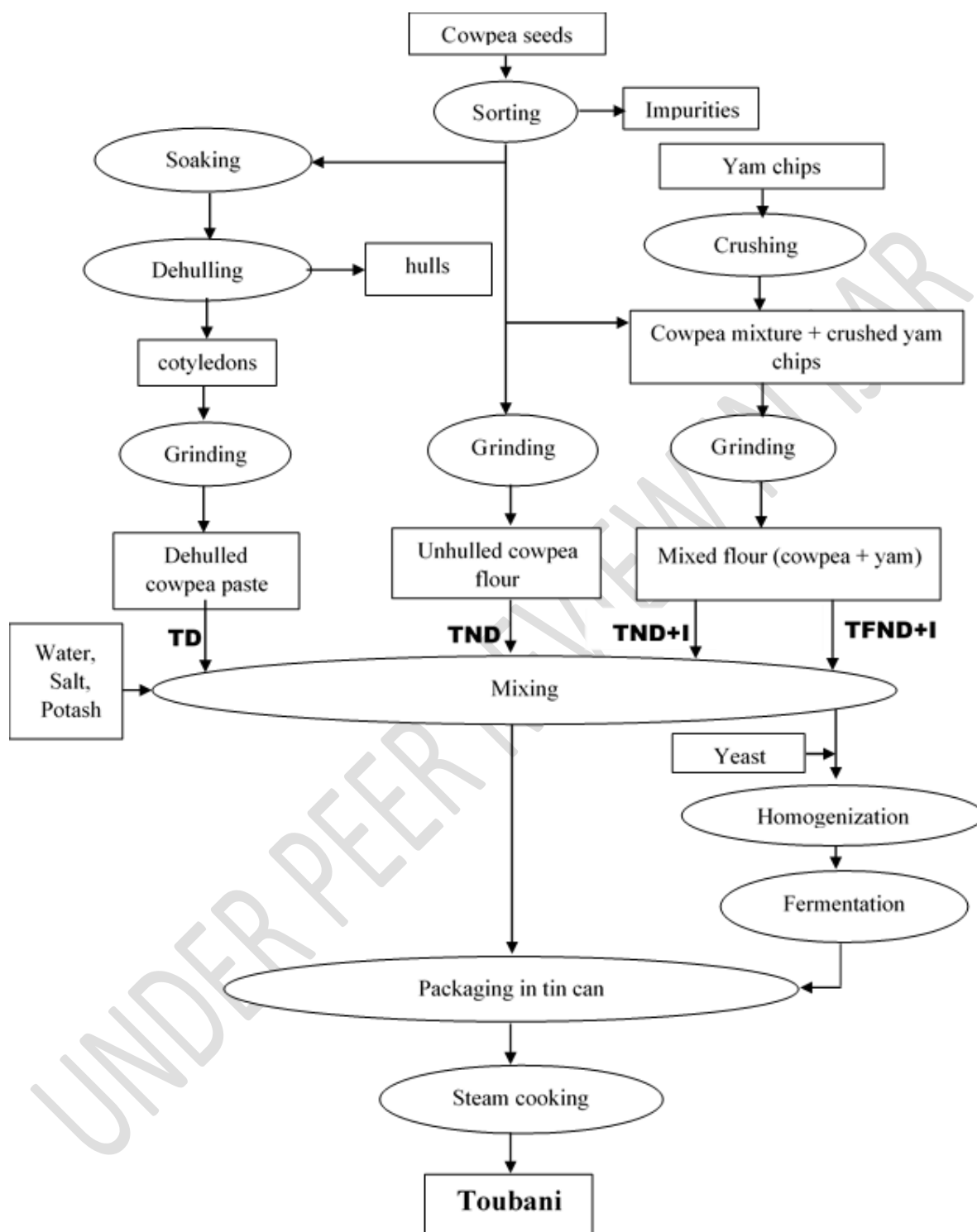


Figure 2 : Technological production diagram of Toubani Variants (Bio Nikki Sarè et al., 2023)

TD = Toubani made from hulled cowpeas ;**TND** = Toubani made from unhulled cowpeas; **TND+I** = Toubani made from unhulled cowpeas plus yam; **TFND+I** = Fermented Toubani made from unhulled cowpeas plus yam.

Physicochemical Analyses and Nutritional Composition of Toubani Samples

- Titratable acidity was determined using the standard method (AOAC 1999).
- The dry matter content of the samples was determined by differential weighing of a 5 g sample before and after passing through an oven at 130°C for 2 hours, according to the French standard (NF V 03-707, 2000).
- Protein content was determined using the Kjeldahl method from the AFNOR standard (NF V03-050), with a conversion factor of 6.25.
- The lipid content was determined according to the ISO standard 659:2009 using the Soxhlet extraction method.
- Total fiber content was determined following the specifications of the standard (NF X43-050).
- Total ash content was determined after calcination at 550°C in a muffle furnace from a sample test until obtaining white or gray ashes according to the AOAC standard (1999).
- Potassium quantity was determined by flame atomic absorption spectrometry according to the AOAC method (2012)
- Carbohydrate content was obtained by calculation according to the method of Egan (1981), as follows: Carbohydrate (%) = 100 - [Protein (%) + Lipids (%) + Ash (%) + Water (%)].
- The energy value was calculated using the coefficients of Atwater and Benedict (1899) according to the following formula: Energy (Kcal/100g) = % Carbohydrates × 4 (Kcal) + % Protein × 4 (Kcal) + % Lipids × 9 (Kcal).
- Nutritional density was determined using the formula: Nutritional Density = (Total Positive Nutrients) / (Total Calories).

Statistical analysis of data

The measured data (physicochemical parameters) underwent one-factor analysis of variance (ANOVA) using R software version 4.3.2 (R Core Team, 2022). Multiple mean comparisons were performed using the Student-Newman-Keuls (SNK) test when the probability $P < 0.05$. All measurements were conducted in triplicate, and the presented data

are the means of these three determinations plus standard deviations. Box plots were created to assess the distributions of nutritional composition and physicochemical characteristics in each Toubani variant representing the processes, utilizing the ggplot2 package in R software(Wickham, 2016).

Multivariate analysis, specifically Principal Component Analysis (PCA), were employed to determine correlations between production processes, physicochemical parameters, and nutritional composition of the studied Toubani variants, utilizing the FactorMiner package in R (Lê et al., 2008). Pearson correlation was used to investigate the interaction between physicochemical characteristics and nutritional composition of Toubani variants, employing the Performance Analytics package in R.

3. Results and discussion

Physicochemical characteristics of Toubani variants

The physicochemical characteristics of Toubani variants are presented in the following Table. The results reveal variations in titratable acidity, dry matter content, ash content, and potassium quantity among the Toubani variants.

Regarding titratable acidity, which indicates the total amount of acid present in the analyzed samples, higher levels are observed in Toubani variants obtained solely from whole cowpea grains without mixing (TD and TND), with values ranging from 12 to 20 Mini equivalents per liter (Meq/L). In contrast, the acidity is significantly lower in other variants obtained after mixing cowpea and yam peels (TND+I and TFND+I). There is a strictly significant difference between the means of titratable acidity in different samples ($p < 0.05$). Additionally, the potassium quantity in TND+I and TFND+I variants is higher compared to TD and TND variants. This indicates that during production, processors use more potash when it involves mixing flours. The proportion of potash appears to be higher when the mixed flour paste undergoes fermentation before cooking, explaining the low pH value (< 0.5 , indicating an initial basic pH of 8.10) obtained in TFND+I variant samples. The addition of potash significantly influences the acidity of Toubani variants. Similar results were obtained with pH values close to alkalinity for cowpea couscous consumed in Mali (Timitéy *et al.*, 2021). It is noteworthy that the significant proportions of potash used in the production of Toubani variants by processors impart a certain hue (coloration) to the products. The coloring and elimination of anti-nutritional factors in cowpea by potash have been reported by various authors (Akissoe, 2021; Cardoso *et al.*, 2021). Colors such as 'White calico' have been assigned to TD variants containing less potassium, while 'Brown' and 'Ashen' have been

assigned to other variants to varying degrees based on the level of dehulling applied to cowpea grains. Unhulled grains produce darker shades in Toubani (Cardoso *et al.*, 2021). The presence of husks and potash imparts dark hues to Toubani. Our results support those of Hongbété *et al.* (2017), who reported a strong correlation between the color of Toubani and dehulling operations followed by the use of potash. According to these authors, products obtained after husking/dehulling of cowpea are darker, as are those that have undergone potash addition.

Furthermore, the dry matter contents of Toubani variants differ between processes, with respective average values of $25.31\% \pm 0.82$; $26.14\% \pm 0.71$; $28.49\% \pm 0.41$; and $29.47\% \pm 0.25$ for TD, TND, TND+I, and TFND+I variants. Significant differences ($p < 0.05$) exist between the dry matter contents of Toubani samples. The dry matter levels of TD and TND variants are not significantly different ($p > 0.05$) from each other but are significantly different ($p < 0.05$) from those of TND+I and TFND+I variants. These values suggest that Toubani obtained after flour substitution has higher dry matter content compared to Toubani obtained without flour substitution. This increase in dry matter content may be due to the contribution of organic materials, fibers, and other nutrients (proteins, carbohydrates) brought by yam peels in addition to the initial content of the base product, cowpea. The high dry matter content of food products contributes to their shelf life or conservation. So, higher the dry matter content, lower will the water activity in the product, and more the product be stable. The increase in dry matter content is proportional to the ash content of Toubani variants. The ash proportions are all below 5%. However, we notice that the proportions are also higher in Toubani variants obtained from whole cowpea grains, unhulled grains, and very low in the TD variant obtained from dehulled cowpea grains. The ash content of the TFND+I variant is significantly different ($p < 0.05$) from that of the other Toubani variants. Dehulling significantly reduces the quantity of inorganic elements present in Toubani samples. Most minerals would be concentrated in the husks and husk envelopes of grains in general and on cowpea husks in particular (Alidu *et al.*, 2020; Gerrano *et al.*, 2017; Gerrano *et al.*, 2022; Naiker *et al.*, 2019).

The dietary fiber content of Toubani variants is higher in the TFND+I variant. This content is significantly different ($p < 0.05$) from that of other Toubani variants, indicating that the Toubani variant obtained after fermenting a mixture of cowpea flour and yam peels is nutritionally richer in dietary fiber. It also attests to the plant origin of the raw materials and the likely ease of digestion of this variant after consumption. Additionally, fermentation and cooking applied during the process could significantly reduce the initially contained anti-

nutritional factors in cowpea. Similar results have been reported for cowpea varieties consumed in Ghana, with fiber contents ranging from 1.56% to 4.47% (Haruna *et al.*, 2018). Kindossi *et al.* (2022) highlighted the effects of fermentation on the modification of the physico-chemical characteristics of protein-rich foods in general and on fish transformed into flavor enhancers. The Institute of Medicine (IOM) recommends the consumption of fiber-rich foods as fibers may reduce the risks associated with cardiovascular diseases and cancer (Hama-Ba *et al.*, 2017).

Regarding energy value and nutritional density, the TFND+I variant provides significantly more kilocalories than the other variants ($p < 0.05$). This is explained by the high carbohydrate content of this variant accentuated by the addition of yam peels during production, which is predominantly rich in starch. Our results support those of Otunola & Afolayan (2018), who highlight significant energy contributions to Moin-moin samples made with 50% yam flour. The TD and TND variants appear to be more nutritionally dense than the other variants due to their high protein contents. These two variants are obtained solely from cowpea.

Table 1 : Physicochemical characteristics and nutritional density of Toubani variants

	TD	TND	TND+I	TFND+I
Titrateable Acidity (Meq/L)	20,03± 1,34 ^a	12,72± 0,72 ^b	4,33± 0,43 ^c	< 0,5 ^d
Dry Matter Content (%)	25,31±0,95 ^a	26,14± 0,81 ^a	28,49± 0,47 ^b	29,47± 0,28 ^b
Ash Content (%)	1,24± 0,17 ^a	1,44± 0,22 ^a	1,67± 0,21 ^a	2,63± 0,36 ^b
Potassium (mg/Kg)	1385,27±2,06 ^a	1501,55± 0,71 ^b	2714,07± 0,91 ^c	3387,72±1,10 ^d
Fiber Content (%)	5,48 ± 0,01 ^a	6,09 ± 0,01 ^b	6,28 ± 0,01 ^b	9,29 ± 0,01 ^c
Energy Value (Kcal)	132,88 ± 0,11 ^a	145,99 ± 0,14 ^b	132,72 ± 0,11 ^a	151,16 ± 0,21 ^b
Nutritional Density	0,21 ± 0,01 ^a	0,21 ± 0,02 ^a	0,18 ± 0,01 ^b	0,19 ± 0,11 ^c

TD = Toubani made from hulled cowpeas; TND = Toubani made from unhulled cowpeas; TND+I = Toubani made from unhulled cowpeas plus yam, and TFND+I = Fermented Toubani made from unhulled

cowpeas plus yam. The means in the same row followed by different letters (a, b, c, and d) are significantly different at the 5% threshold. Note: each parameter was replicated three times

Nutritional profile of Toubani variants

Carbohydrate, protein, lipid, and vitamin contents of Toubani variants were determined, and Figure 3 illustrates the variability of results for each determined parameter. The results reveal that variants TD and TND, exclusively made from cowpea without any mixture, are richer in proteins, with average values ranging between $23.42\% \pm 0.62$ and $26.01\% \pm 0.65$, compared to $18.57\% \pm 0.42$ and $19.48\% \pm 0.51$ for variants TND+I and TFND+I, which result from a mixture of cowpea flour and yam peels. The protein content of variant TND is higher than that of TD, indicating that dehulling has partially reduced the protein content of Toubani. The manual dehulling process of cowpea grains, without proper equipment, likely eliminates part of the protein-rich cotyledons along with the husks due to the lack of adequate materials. Similar to our results, a decrease in protein levels in variants of "shôbasi," a cowpea couscous consumed in Mali, produced after partial dehulling of grains, was observed by Timitey *et al.* (2021). Furthermore, ANOVA analysis shows significant differences ($p < 0.05$) between the mean protein contents of samples from TND, TND+I, and TFND+I variants obtained from different processing methods (Figure 3-1). This figure also demonstrates a significant difference between protein contents within each Toubani variant, except for variant TD, where the differences are not significant. Thus, we conclude that dehulling significantly reduces the protein content, while flour substitution and fermentation have little effect on this variation. These findings align with studies by Cardoso *et al.* (2021); Devi *et al.* (2015); Teka *et al.* (2020) on the effect of processing on cowpea's nutritional composition.

The average carbohydrate contents of Toubani variants (TND+I and TFND+I) obtained after a mixture of cowpea flour and yam peels are significantly higher than those of variants obtained solely from cowpea without mixing (TD and TND). This variation could be explained by the combination of carbohydrate contributions from the raw materials used in producing these variants. Yam peels used in mixtures, being derived from yam tubers, are predominantly rich in starch, a macromolecule composed of multiple carbohydrates according to (Ratnaningsih *et al.* (2020). Some authors, such as Affrifah *et al.* (2022); Cardoso *et al.* (2021); Otunola & Afolayan (2018), have reported similar results on the high carbohydrate content of traditional foods made from roots and tubers and foods made from a combination of legumes and tubers. Variant TFND+I contains more carbohydrates than the other variants. As this variant is obtained after fermentation facilitated by *Saccharomyces cerevisiae* yeast, a substantial proportion of starch may have been added to serve as a fermentable substrate for

the yeast. Similar to our findings, Otunola & Afolayan (2018) emphasized the high carbohydrate content of moin-moin types obtained from a mixture of cowpea flour and yam. Furthermore, ANOVA analysis indicates a significant difference ($p < 0.05$) between the processing methods of different variants (Figure 3-2). This difference is not noticeable within the samples of variant TD and also within the samples of variant TND+I. We conclude that flour substitution or mixing significantly contributes to increasing the carbohydrate content of Toubani variants (Cardoso *et al.*, 2021; Otunola & Afolayan, 2018).

All Toubani variants have very low lipid contents, below 1% ($<1\%$) (Figure 3-3). We observe that the various production processes applied during the preparation of different variants do not provide additional quantities of lipids or fats to the final products obtained after cooking. Cowpea is a legume low in lipids. Therefore, ANOVA does not show significant differences ($p < 0.05$) among the different variants and processing methods of Toubani (Figure 3-3). The low lipid contents of legumes in general and cowpea have been highlighted by Kirse & Karklina (2015). Some authors also emphasize the low lipid contents of foods derived from the processing of legumes in general and cowpea in particular (Hama-Ba *et al.*, 2017; Timitéy *et al.*, 2021).

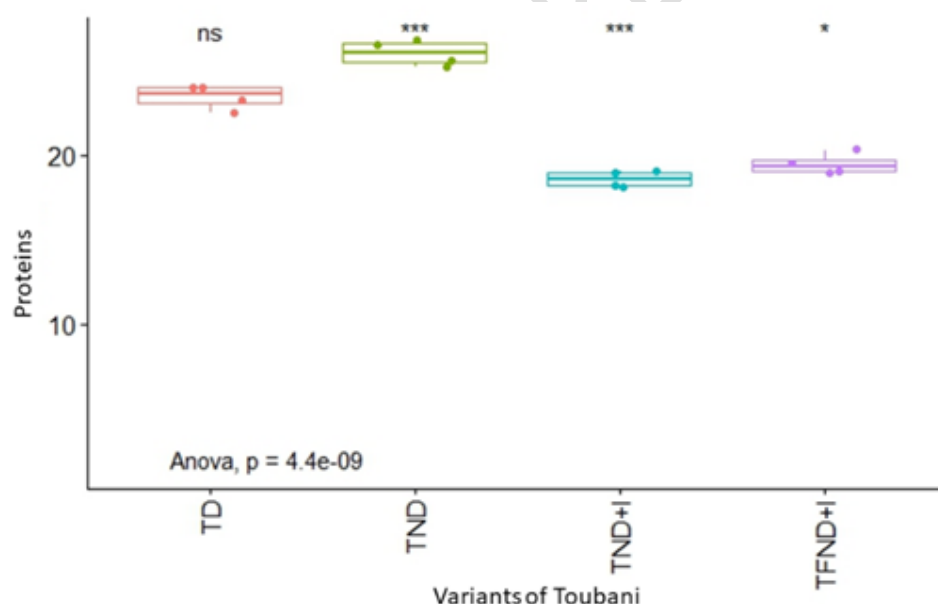


Figure 3-1 : Effect of production processes on protein content of Toubani variants

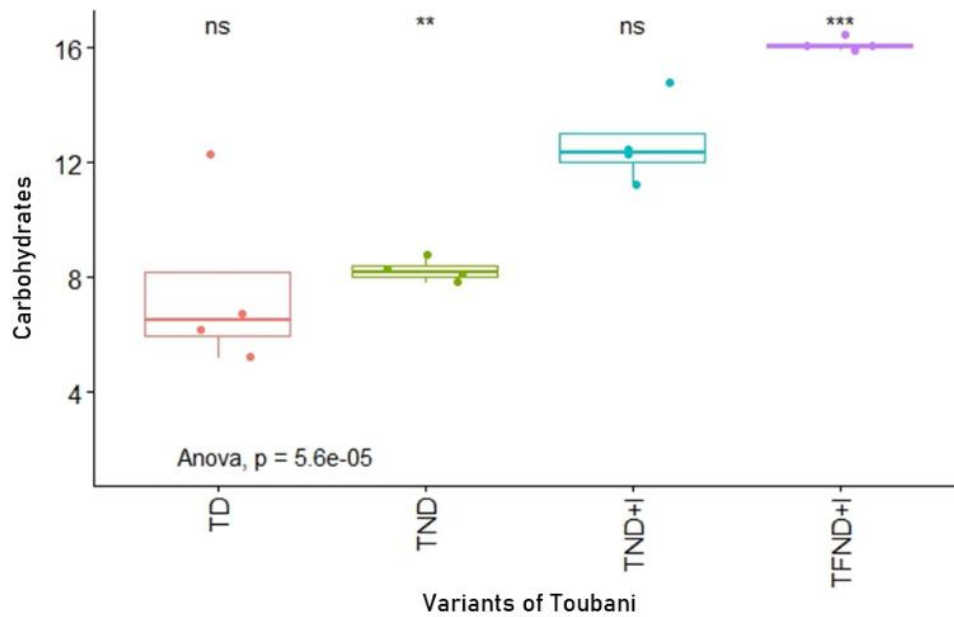


Figure 3-2 : Effect of production processes on carbohydrate content of Toubani variants

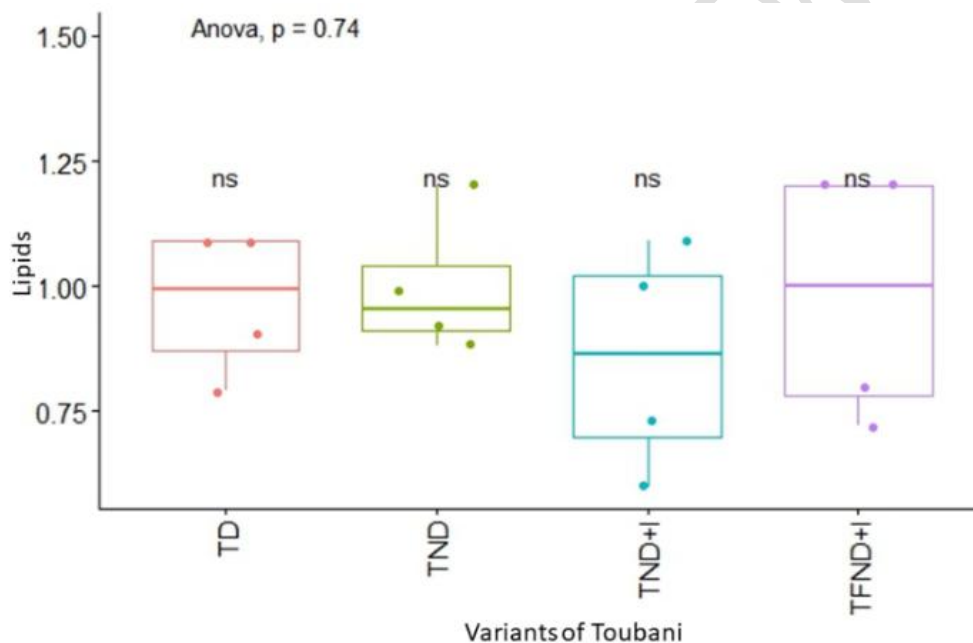


Figure 3-3 : Effect of production processes on lipid content of Toubani variants

TD = Toubani made from hulled cowpeas; TND = Toubani made from unhulled cowpeas; TND+I = Toubani made from unhulled cowpeas plus yam, and TFND+I = Fermented Toubani made from unhulled cowpeas plus yam. **ns** = no-significant difference.

Correlation between physico-chemical characteristics and nutritional composition of Toubani variants

The relationship between the physico-chemical characteristics and the nutritional composition of Toubani variants is depicted in the Principal Component Analysis (PCA) graph presented in Figure 4. The PCA reveals that 73.56% of the characteristics of the Toubani variants are highly correlated (Dim1), around the TFND+I and TND+I variants, while 24.20% of the characteristics are weakly correlated (Dim2), around the TND and TD variants. There is a strict correlation between certain physico-chemical characteristics and certain nutritional components as shown in the biplot. Table 2 show that Carbohydrate content is significantly and positively correlated with dry matter content ($r = 0.98$; $p < 0.05$) on one hand and is significantly and negatively correlated with titratable acidity ($r = -0.95$; $p < 0.05$) on the other hand. There was also a significant positive correlation between proteins content and nutritional density ($r = 0.97$; $p < 0.05$). Here, this correlation was even stronger for the TND variant. We have noticed that the increase in dry matter content is proportional to the carbohydrate and ash content. Fermentation and other bioprocesses appear to have a significant effect on the chemical composition of food products (Awoyale *et al.*, 2023). PCA shows a weak positive correlation between titratable acidity and protein content ($r = 0.76$; $p < 0.05$). This correlation can be observed for the TD and TND variants, which are obtained exclusively from cowpea grains without flour mixing. For these two Toubani variants, the use of a small amount of potash to facilitate cooking and eliminate antinutritional factors, followed by a large amount of common salt, would explain the increase in their titratable acidity. Similarly, protein content was significantly and negatively correlated with dry matter content ($r = -0.84$; $p < 0.05$) contrary, carbohydrates, dry matter, fibers, ash and energy value are positively correlated ($r = -0.88 < r < 0.99$; $p < 0.05$). This correlation is accentuated for the TND+I and TFND+I variants. Our results corroborate those of Hongbété *et al.* (2017), who showed a correlation between the quality attributes of cowpea-based foods and their technological processes.

The strong correlations observed make it possible to understand the effect of technological production processes on the physico-chemical characteristics and nutritional composition of Toubani. Consequently, the findings obtained can be used to guide the formulation, replacement and selection of raw materials and ingredients used in the production of Toubani in order to improve its quality.

Table 2: Correlation coefficient between physico-chemical characteristics and nutritional composition of Toubani variants

Proteins	-0.83	0.69	-0.52	0.11	0.97*	0.76	-0.84	-0.61
Carbohydrates	-0.25	0.89	0.46	-0.90*	-0.95*	0.98*	0.94*	
Lipids	0.20	0.66	0.65	0.34	-0.36	0.86		
Fibers	0.77	-0.61	-0.80	-0.83	0.99**			
Energy	-0.063	-0.47	0.41	0.71				
N.Density	0.89	-0.93*	-0.70					
Acidity	-0.99*	-0.86						
Dry matter		0.89						
Ash								

Proteins = proteins content ; Lipids = lipids content ; Fibers = fibers content ; Ash = ash content ; Carbohydrates = carbohydrates content ; Potassium = potassium content ; Drymatter = dry matters content ; Acidity = titratable acidity and N.Density = nutritional density

* = correlation ; P = 0.001 ; ** = correlation P = 0.01; *** = correlation P = 0.05

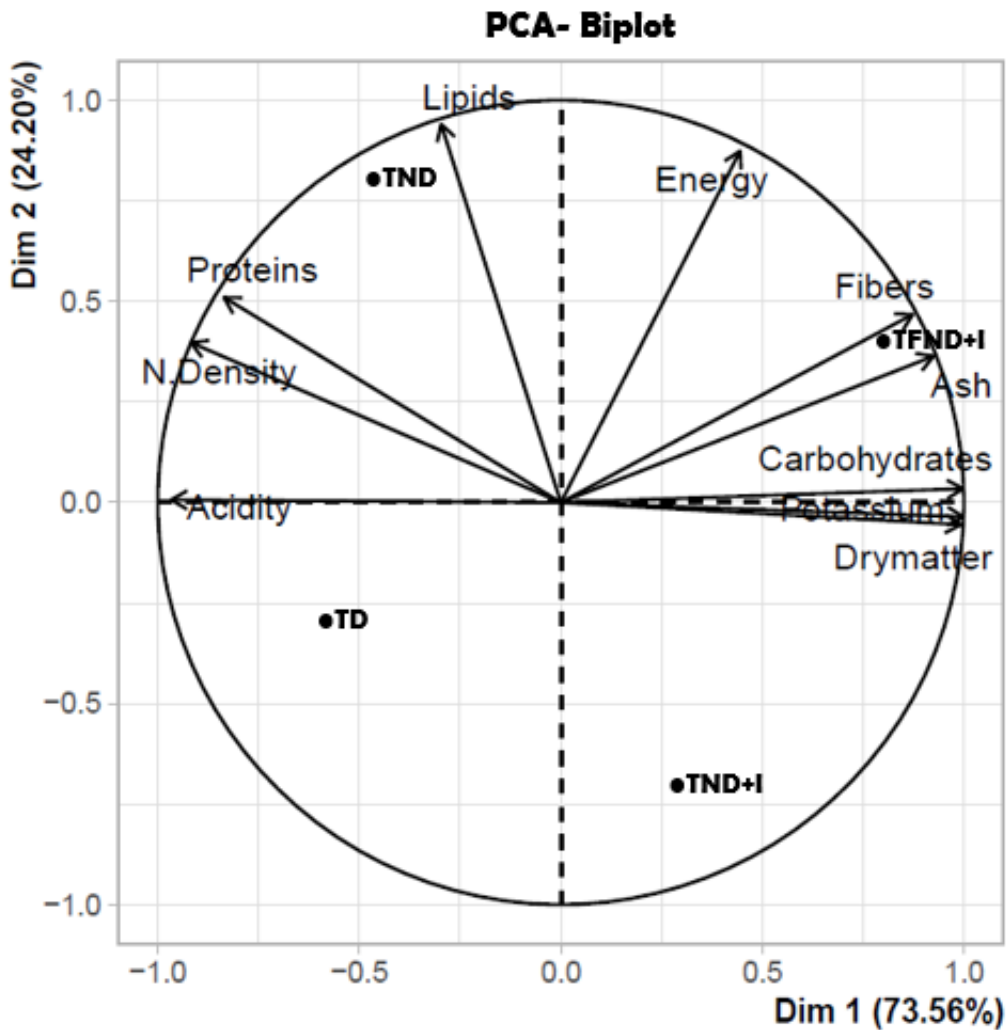


Figure 4 : Relationship between physico-chemical characteristics and nutritional composition of Toubani variants

TD = Toubani made from hulled cowpeas; TND = Toubani made from unhulled cowpeas; TND+I = Toubani made from unhulled cowpeas plus yam ; TFND+I = Fermented Toubani made from unhulled cowpeas plus yam ; Proteins = proteins content ; Lipids = lipids content ; Fibers = fibers content ; Ash = ash content ; Carbohydrates = carbohydrates content ; Potassium = potassium content ; Drymatter = dry matters content ; Acidity = titratable acidity and N.Density = nutritional density

Acknowledgments

We extend our sincere thanks to the actors involved in the production-sale and consumption of Toubani, for their contributions to achieving the objectives of this research.

Conflict of interest statement

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

4. Conclusion

This study holds paramount importance in unraveling the physico-chemical and nutritional nuances of four Toubani variants, providing valuable insights into their production processes. The findings underscore the impact of dehulling, substitution, and fermentation on key nutritional parameters. As a next step, future research should focus on optimizing these processing techniques to develop standardized methods, ensuring consistency and quality across Toubani production. Additionally, exploring sensory attributes and consumer preferences will be crucial for enhancing market acceptance. Another key future direction lies in efforts to improve the nutritional quality, assess shelf-life, and ensure microbiological safety of Toubani products. By addressing these aspects will not only contribute to the advancement of Toubani production practices but also promote the development of nutritious and culturally significant food products, fostering sustainable and health-conscious dietary practices.

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