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Formulation and Acceptability of Broth Powders Based on Fermented *Zamné* (*Senegalia macrostachya*) Seeds

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Fermented *Zamné* is a nutritionally valuable condiment, rich in protein, lipids, and minerals. However, its strong odor and alkaline taste negatively affect its consumer acceptability. To improve its acceptability, dehulling and formulation into broth powder products were investigated. Preference test, hedonic profile and ranking test were used to evaluate sensory parameters of samples. Moisture, pH, ash content, fat content, protein and carbohydrate were then determined. Sensory test indicated that dehulling significantly improved its sensory acceptability, likely by improving the color and reducing undesirable flavor attributes. Based on this result, dry broths were formulated by blending dehulled fermented *Zamné* with selected ingredients (Onion leaves, black pepper, garlic, ginger and salt). Hedonic test showed that the taste, aftertaste, smell and color of all the broths were appreciated. Among the formulations, F5 containing 60% of dehulled fermented *Zamné* and 40% of added ingredients received the highest overall acceptance score. Biochemical analysis revealed that dehulled fermented *Zamné* had higher protein (38.98 ± 0.24 g / 100 g DM) and lipids contents (28.15 ± 0.68 g 100 g DM) compared to the formulated broths (from 30.23 to 35.18 g / 100 g DM and from 15.91 to 23.81 g / 100 g DM, respectively). In contrast, the formulated broths showed higher ash content (6.47-9.50 g / 100 g DM). Overall, dehulling combined with ingredient incorporation significantly improved the sensory properties and acceptability of fermented *Zamné*.

Keywords: Broths, Condiment, Fermented *Zamné*, Hedonic test, *Senegalia macrostachya*.

Fermentation has been used worldwide as a mean of preserving food and increasing its nutritional value. In Africa and worldwide, alkaline fermented foods constitute an important component of the daily diet of many people.[1] These products are commonly used as condiments and serve as a tasty, low-cost protein source. In Africa, these foods have a large impact on the nutrition, health and socioeconomy of people. In Burkina Faso, *soumbala* produced through the fermentation of *Parkia biglobosa* seeds is the most widely known and consumed condiment.[2] This alkaline fermented product is particularly valued for its high protein content, typically ranging from 39.91 to 41.19%.[3,4] In addition to *soumbala*, several other local seeds are traditionally fermented and used as condiments

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in Burkina Faso. Among them, fermented *Zamné*, derived from *Senegalia macrostachya* seeds, represents a lesser-known but nutritionally promising product. The seeds are typically boiled and subjected to alkaline fermentation for approximately 48 hours.[5] Fermented *Zamné* is mainly produced and consumed in the central region of Burkina Faso.[6] With a high protein content (48.91 ± 0.74 g / 100 g DM) and significant amounts of important minerals like potassium, magnesium, and iron, it is nutritionally similar to soumbala.[4]

Despite these nutritional attributes, the adoption of fermented *Zamné* remains limited. Previous studies have reported that its sensory attributes, particularly its strong odor, dark color, and pronounced taste, are less appreciated compared to *soumbala*.[7] These characteristics negatively influence consumer acceptance and hinder its integration into people regular dietary habits. Improving the sensory quality and acceptability of fermented *Zamné* is therefore essential to promote its consumption.[8] Processing strategies such as dehulling may reduce undesirable sensory attributes, while product reformulation could enhance its consumer appeal.[5] In this regard, the current study sought to assess how dehulling and new product formulation affected the fermented *Zamné* sensory quality. Specifically, dry broth powders were developed using dehulled fermented *Zamné* combined with selected ingredients, and their acceptability was assessed through sensory evaluation. Proximate composition was assessed to evaluate their nutritional composition.

MATERIALS AND METHODS

Zamné and ingredients Samples collection

Zamné (*Senegalia macrostachya* seeds) was purchased from a local market in Ouagadougou, Burkina Faso. The additional ingredients used for broth formulation, including garlic, onion leaves, black pepper, ginger and salt were purchased from the same local market.

Production of fermented *Zamné*

The Department of Food Technologies of the Research Institute in Applied Science of Burkina Faso's (IRSAT/DTA) pilot food processing unit produced the fermented seeds. Non-dehulled fermented *Zamné* was produced after cooking cleaned seeds in water for 30 minutes, then draining and washing. After adding potash (1%, w/w), a second cooking step was carried out. The cooked seeds were drained, inoculated with previously prepared *soumbala* (2%, w/w) as a starter culture, and fermented at room temperature (25-30 °C) in a fermentation vessel for 48 h. The fermented product was subsequently sun-dried for 72 h. For the dehulled fermented *Zamné*, the seeds were dehulled after the initial cooking step. The dehulled seeds were then subjected to a similar processing as described above: second cooking process (30 min with 1% potash), inoculation (2% *Soumbala*), and fermented at room temperature in a fermentation vessel for 48 h. The final product was also sun-dried for 72 h.

Preparation of ingredients

Garlic, onion leaves, black pepper, and ginger were washed and dried in a dryer at 55 °C for 8 h. The dried materials were then milled using a hammer mill equipped with a 600 µm sieve to obtain fine powders.

Formulation of dry broths

A preliminary preference test was conducted to compare dehulled and non-dehulled fermented *Zamné*. The most preferred product was found to be dehulled fermented *Zamné*, and was selected as the base ingredient for broth formulation. Dry broths were formulated by varying the proportion of fermented *Zamné*, which was considered as the main factor influencing sensory acceptability.[4] Six formulations were prepared, with fermented *Zamné* levels ranging from 50% to 100%, mixed with the powdered ingredients (garlic, onion leaves, black pepper, ginger, and salt). The composition of the different formulations is presented in Table 1.

Beef broth production

For the culinary test, the beef broth was prepared according to the method described by Sawadogo-Lingani et al.[9] In fact, in many West African countries, fermented condiments are widely used for preparing soups and stews.[10] Beef broth was prepared by cooking 2 kg of meat (beef) in water (5 L) with onions and salt as condiments. The meat was removed at the end of cooking. This broth was then divided and mixed with dehulled fermented *Zamné* and non-dehulled fermented *Zamné* (100 g in 1 L of beef broth) and cooked for 5 minutes. Beef broth was used only for the

preference test between dehulled fermented *Zamné* and non-dehulled fermented *Zamné.*

Analysis methods

Ethical Clearance and recruitment of participants

This study was approved by the Health Research Ethics Committee of the Ministry of Health of Burkina Faso on December 3, 2025, authorization number: 2025-12-541. The participants constituted an untrained consumers panel composed of students from Ouagadougou universities and personnel from the Department of Food Technology. The study was presented to the volunteers, who were familiar with the consumption of fermented condiments, as a sensory analysis of fermented *Zamné*. All methods were carried out in accordance with the sensory analysis methods according to test type. Informed consent was obtained from all the participants (age > 18 years) involved in the study.

Sensory analyses

Three (03) tests were selected for the sensory evaluations of the samples.

Preference test

The preference test allows consumers to express a choice between samples. One sample is preferred and chosen over another, or there is no preference. Panelists are asked which of two coded samples they prefer.[11] The aim was to determine which condiment between dehulled fermented *Zamné* and non-dehulled fermented *Zamné* was most appreciated. Fresh samples, powders of dry samples, and beef broth containing the powders (culinary test) were evaluated. The six samples were presented together and evaluated in pairs. The most liked was used for the formulation of broth powders.

Ranking tests

Ranking tests require panelists to order samples according to the perceived intensity

Table 1. Composition of broth formulations

Composition Formulation Number	Fermented *Zamné*	Onion leaves powder (%)	Black pepper (%)	Garlic (%) (%)	Ginger (%)	Salt (%)
F1	100	0	0	0	0	0
F2	90	2	2	2	2	2
F3	80	4	4	4	4	4
F4	70	10	5	5	5	5
F5	60	15	5	10	5	5
F6	50	15	5	15	10	5

Table 2. Panel composition

Total participants	Information on the Participants					Sensory analysis	Samples evaluated
	Age (%)			Gender (%)			
	18-30	31-40	over 40	Female	Male		
29	96.6	0	3.4	58.6	41.4	Preference test (fresh samples)	(Non dehulled and dehulled fermented *Zamné*
33	87.9	9.1	3	66.6	33.3	Preference test (dry samples (powder) and in broths)	
30	76.66	6.66	16.66	53.33	46.66	1st ranking tests	All formulated broths
28	89.29	3.57	7.14	42.86	57.14	2nd ranking test and hedonic tests	Selected formulated broths and dehulled fermented *Zamné*

of a sensory characteristic order from the most acceptable to the least acceptable.[11] For the ranking test, the six formulations of broth were divided into two groups of three. The two best formulations from each group were selected and submitted to a final ranking test.

Hedonic tests

Hedonic tests are designed to measure the degree of liking for a product by choosing the appropriate category.[12] The selected formulations (04) and dehulling fermented *Zamné* were subjected to this test. The participants were asked to appreciate the color, smell, taste, aftertaste, and overall acceptability of the products using a labeled 5-point hedonic scale.

Biochemical analysis

The measurement of pH was carried out according to AOAC 981.12.[13] Moisture was estimated by desiccation with the drying oven at 105°C. The ash content was estimated by incineration at 550°C. Protein was determined using the Kjeldahl method. The determination of the fat content is made according to the method of extraction by Soxhlet using hexane as solvent. Carbohydrate was determined by the differential method.

Statistical analysis

Data were collected using Microsoft Excel 2019. An analysis of variance (ANOVA) was performed with XLSTAT (version 2016.02.27444) to investigate differences between percent-composition variables. SPSS Statistics (version 27) was used to assess differences between sensory parameters. For the preference test, a chi-square goodness-of-fit test was applied to each product category. Ordinal data from the rankings were analyzed using Friedman's nonparametric test. In cases of significant differences, the Newell and MacFarlane multiple comparisons post-hoc test and the Nemenyi test were applied to identify distinct samples. For all analyses, differences were considered statistically significant for a p-value < 0.05.

RESULTS

Panel Composition

The composition of the panel is summarized in Table 2. The sensory panel consisted of 29 and 33 tasters (women and men) for the preference test and 30 tasters for the first ranking test. 28 tasters, females and males, aged from 18 to over 40, made the second ranking and hedonic tests. The 18- to 30-year-old age group represented 76% to 96% of the participants across the panel.

Sensory Characteristics

Preference test

Figure 1 presents the results of the preference test. The powder of fermented dehulled *Zamné* and beef broth with fermented

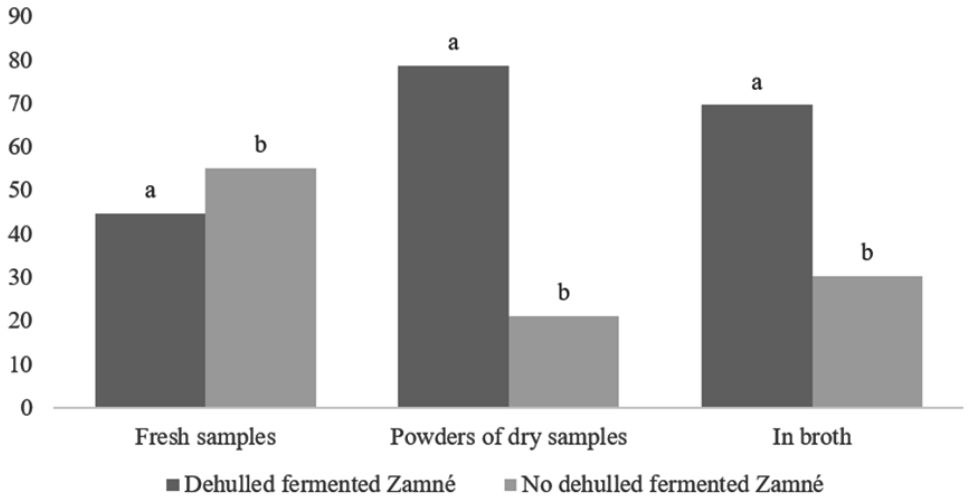


Fig. 1. Results of the preference test

Histograms of the same group topped with different letters indicate a statistically significant difference (chi-square test, $p < 0.05$)

dehulled *Zamné* showed a statistically significant preference, receiving 78.8% and 69.7% of the votes, respectively (chi-square test, $p < 0.05$). Conversely, for the fresh samples, although the non dehulled fermented *Zamné* obtained a higher score (55.2% versus 44.8%), this difference was not statistically significant ($p > 0.05$), indicating similar sensory acceptability between the two fresh variants.

Ranking test

Statistical analysis of the two ranking tests (Friedman test, alpha = 0.05) revealed significant differences between the samples (Figure 2). In the first group, formulation F4 ranked first (chosen by 43.3% of judges), followed by F6 (33.3%). Their sums of ranks were significantly lower ($p < 0.05$) than those of the other products, indicating a clear preference. In the second group, F3 obtained first

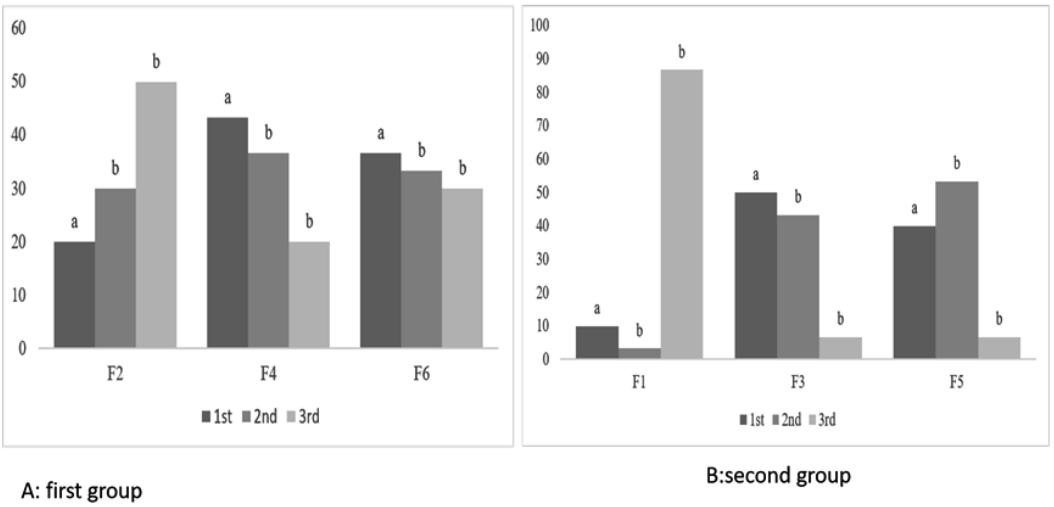


Fig. 2. Results of first ranking tests (A: first group, B: second group)
Within the same group, samples sharing the same letter did not show a statistically significant difference $p < 0,05$

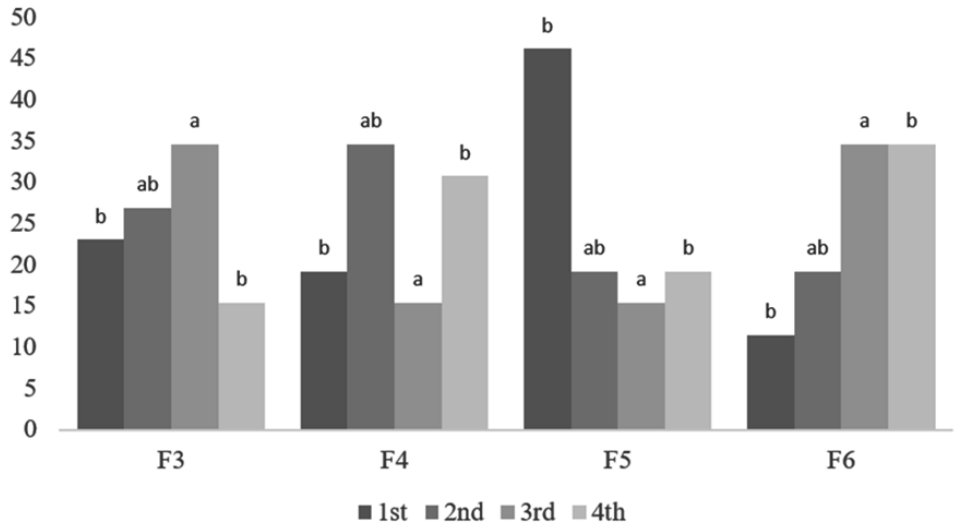


Fig. 3. Second ranking test results
Different letters above the bars indicate statistically significant differences between the formulas ($p < 0.05$ according to Nemenyi's post-hoc test following a significant Friedman test at $p = 0.0014$)

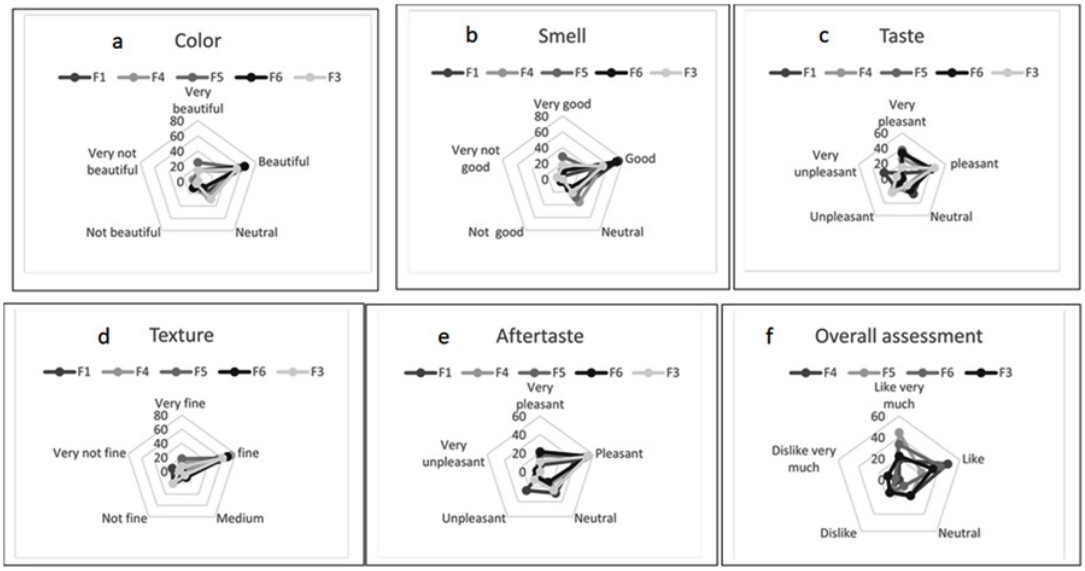


Fig. 4. Hedonic test results of fermented *Zamné* and formulated dry broths: (a) color, (b) smell, (c) taste, (d) texture, (e) aftertaste, and (f) overall assessment. Values represent the distribution of panelist appreciations on a 5-point hedonic scale.

place (50% of the panel) and F5 second place (53,3% of the panel). Multiple comparison tests confirmed that the performance of F4, F6, F3, and F5 were statistically superior to that of the control F1 (*Zamné* 100% fermented) and F2.

The ranking test results reveal highly significant differences in appreciation among the four formulas (Friedman test, $p = 0.0014$). These results (Figure 3) show that sample F5 is the most appreciated, having been ranked first by 46.2% of panel members. Sample F4 comes in second place (34.6%). Samples F3 and F6 share the majority of the lower rankings, both coming in third place with 34.6% of the votes; F6 also receives 34.6% of the votes for fourth place. The Nemenyi post-hoc test indicates that formula F5 stands out significantly from formulas F3 and F6 ($p < 0.05$).

Hedonic test

According to the panel, the samples evaluated (F3, F4, F5 F6 and F1(control)) have a beautiful color, a good smell and a pleasant taste and aftertaste. The texture of all the samples is appreciated as "fine". Formulation F1 used as control (100% fermented *Zamné)* perfomed poorly against the four broth formulations. Concerning the overall assessment of the four formulated broths (F3, F4, F5 and F6), F5 received the highest observed proportion of first-place rankings compared to the other formulations. In fact, the panel (44.4 %) "like very much" this formulation, while formulations F3, F4 and F6 were just "liked" by 33.3%, 48.1%, and 40.7% of the panel, respectively. The aroma of all the samples was liked. The P-values of chi-square test were greater than 0.05, indicating that there are no significant differences between the correlations of the sensory parameters. The results of hedonic tests are illustrated in Figure 4.

Proximate composition

As seen from Table 3, pH values of non-dehulled fermented *Zamné* (6.2) and dehulled fermented *Zamné* (6.23) are higher than those of formulated broths (from 5.80 to 6.14). The protein content of formulated broths varies from 30.23 to 35.18% of dried matter. These values are lower than those of non-dehulled fermented *Zamné* and dehulled fermented *Zamné*, 36.61 and 38.98% respectively. However, formulated broths showed a higher content of ash (6.47-9.5). Water content, fat and carbohydrate contents of all the samples were within the same range. Statistical analyses showed a significant difference between ash, lipids, protein and carbohydrate contents of non dehulled fermented *Zamné* and those of dehulled fermented

Table 3. Proximate composition of fermented *Zamné*, dehulled fermented *Zamné* and formulated broths

Samples	Moisture (%)	pH	Ash (g / 100 g DM)	Lipids (g / 100 g DM)	Proteins (g / 100 g DM)	Carbohydrates (g / 100 g DM)
Non-dehuled fermented *Zamné*	4.78 ± 0.15^{b}	6.2 ± 0.04^{e}	3.02 ± 0.04^{b}	23.33 ± 0.34^{e}	36.61 ± 1.21^{c}	37.04± 0.97^{c}
Dehulled fermented *Zamné*	4.19 ± 0.08^{a}	6.23 ± 0.01^{c}	2.18 ± 0.04^{a}	28.15 ± 0.68^{d}	38.98 ± 0.24^{d}	30.69± 0.14^{b}
F3	4.74 ± 0.08^{b}	6.14 ± 0.05^{bc}	6.47 ± 0.13^{c}	23.81 ± 0.48^{e}	33.93 ± 0.79^{b}	35.79± 0.64^{c}
F4	5.14 ± 0.16^{c}	5.99 ± 0.06^{ab}	8.09 ± 0.22^{d}	20.76 ± 0.93^{b}	35.18 ± 0.35^{bc}	35.97± 0.43^{c}
F5	5.68 ± 0.10^{d}	5.80 ± 0.13^{a}	9.16 ± 0.18^{e}	18.96 ± 1.25^{b}	34.18 ± 0.41^{b}	37.7± 0.83^{c}
F6	6.31 ± 0.09^{e}	5.82 ± 0.08^{a}	9.50 ± 0.25^{e}	15.91 ± 0.30^{a}	30.23 ± 0.16^{a}	44.36± 0.14^{d}
P-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

In the same column for the same product, means with the same superscript letters are not significantly different with P > 0.05.

Zamné. Some differences were observed between fermented seeds and formulated broths for pH, ash and protein contents.

DISCUSSION

In the present study, we investigated the effect of dehulling on the sensory acceptability and nutritional quality of fermented *Zamné*, and subsequently developed dry broth formulations with selected seasoning ingredients to enhance its sensory attributes. The age demographics show an overwhelming concentration of young participants (76%-96% in the 18–30 age group). The preference test indicated that dehulled fermented *Zamné* was more acceptable than the non-dehulled product. This difference can be primarily attributed to variations in sensory attributes, particularly color, aroma, and taste. The darker color observed in non-dehulled fermented *Zamné* may negatively influence consumer perception. When making food choices, color is important in guiding consumer preferences.[14] Moreover, the dehulling likely affected the level of fermentation by reducing the presence of seed coat components, which may contribute to undesirable flavors and odors. Similar effects have been reported for *soumbala*, where processing methods, including dehulling, significantly influence aroma. Furthermore, the difference in protein content could also affect the flavor. Ouoba et al.,[15] reported in their study that the flavour properties of *Soumbala*, a fermented seeds of *Parkia biglobosa,* are most likely due to its amino acid content. Based on these findings, dehulled fermented *Zamné* was selected for broth formulation. Hedonic evaluation showed that the control sample (100% fermented *Zamné*) was less appreciated than all formulated broth formulations, indicating that incorporation of the seasoning ingredients improves the product's acceptability. The aroma was generally well appreciated across all formulations, confirming its central role in consumer acceptance of fermented condiments. Among the formulations, F5 (60% fermented *Zamné* and 40% added ingredients) exhibited a numerical trend towards higher preference, receiving the highest proportion of first-place rankings. However, chi-square analysis revealed no statistically significant differences ($p > 0.05$) among the core parameters of the four enriched

formulations (F3 to F6). This suggests that while F5 presents a favorable sensory balance, it remains statistically comparable to the other broth formulations. Appiah et al.,[10] reported that the most important predictive factor for the acceptability of fermented condiments is aroma. Therefore, the improvement of the sensory acceptability observed in the formulated broths can be attributed to the combined effects of dehulling and the addition of flavoring ingredients, which likely reduced off-flavor and enhanced overall sensory balance. So, these condiments could be used to diversify people's diets. In fact, diets in West Africa often lack variety and consist of large quantities of the staple food.[16] *Zamné* seeds had already demonstrated unique sensory attributes that could facilitate their promotion in human diets.[17]

Proximate composition revealed an increase in moisture content of formulated broths compared to fermented *Zamné*, which may be attributed to the processing conditions. Nevertheless, the moisture content of fermented *Zamné* (dehulled and non-dehulled) remained lower than those reported for similar fermented condiments such as *soumbala* and other fermented seeds including *Parkia biglobosa*, *Glycine max* and *Treculia africana* (10.23%, 11.41% and 11.40%, respectively). The preservation of foods by drying is a direct consequence of removal or binding of moisture, without which microorganisms do not grow. Shelf life can be reduced or lost due to microbial, physical, and chemical changes in food. Although the moisture contents were relatively low, water activity was not measured; therefore, microbial shelf stability can not be established from moisture content alone.

Unlike acidic fermentations, where pH may drop to 2-4 after fermentation due to organic acid production, alkaline fermentation is characterized by relatively high pH values, primarily resulting from the release of ammonia and other basic compounds during microbial proteolysis. Compared to the dehulled and non-dehulled fermented *zamné*, the formulated dry broths exhibited lower pH values. This decrease can be attributed to the addition of ingredients, which may contribute organic acids or other acidifying compounds. The pH values obtained are similar to those reported by Owusu-Kwarteng et al.,[18] for fermented *Zamné* and *kawal* (pH 5.87-7.22), respectively. However, the values were lower than those of *Soumbala* (6.3 to 7.8). Moreover, a higher ash content of the broth powders compared to fermented *Zamné* (dehulled and non-dehulled) was noticed. This could be due to the added mineral-rich ingredients.

An important part of this mineral content could be due to the salt. The addition of food-grade salt (5% w/w in formulations F4, F5, and F6) directly impacts the mineral profile of the dry broths. For instance, in formulation F5, which exhibited a total ash content of 9.16 g / 100 g DM, the added salt accounts for approximately 54.6% of the total mineral fraction. While salt enhances palatability and sensory acceptance, a 5% inclusion rate introduces a non-negligible sodium load. From a nutritional and public health perspective, elevated sodium intake is closely linked to arterial hypertension and cardiovascular risks. Therefore, while these fermented *Zamné* broths represent excellent sources of plant-based protein, future optimization studies should focus on reducing the sodium load potentially through the integration of potassium-based salt substitutes to align the final product with global health guidelines. Food-grade salt consists primarily of sodium chloride, with a minimum content of 97%.[19] Additionally, the higher ash content in non-dehulled fermented *Zamné* compared to the dehulled form is likely due to the presence of the seed coat.[3] Ash content is a measure of the total mineral content of food products.[6] However, ash is a nonspecific measure of minerals and does not give information about the mineral profile. The ash content of fermented *Zamné* and the prepared broths suggests that they may contain various minerals. So, the mineral profile of fermented *Zamné* and formulated broths need to be investigated. The high protein content of fermented condiments makes them suitable for use in combating protein malnutrition.[10] As reported by Guissou et al.,[20] *Senegalia macrostachya* seeds are rich in proteins with values ranging from 37.7% to 40.08%. In our study, a marked decrease in the protein and lipid contents in the formulated broths compared to the fermented *Zamné* was observed. This result can be attributed to the dilution effect resulting from the addition of other ingredients (Onion leaves, black pepper, garlic, ginger, salt) which have lower protein content. Nevertheless, the protein levels remain relatively high, confirming the

nutritional potential of the fermented *Zamné* and formulated broths. Compared to other fermented condiments, the protein content of fermented *Zamné* is comparable to that of *soumbala* but lower than that reported for *kinema, a fermented* soybean-based products.[21] Appiah et al.,[10] reported a protein content of 21.28% in fermented seeds of *Treculia africana*, which is lower to that of fermented *Zamné.* The fat content of fermented *Zamné* was also higher than those reported for fermented seeds of *Adansonia digitata* (*Maari*), *Glycine max* and *Treculia Africana*. Given their fat content, fermented condiments could be a source of fat-soluble vitamins and also be used as flavor enhancers. The fat content could contribute significantly to meeting the daily lipid requirement of consumers. Nutritionally, dehulled fermented *Zamné* condiment can be considered as a superior source of fat and protein compared to non-dehulled fermented *Zamné*.

We also noticed a significant decrease in carbohydrate content in the dehulled fermented *zamné* compared to the non-dehulled sample. This decrease in carbohydrate content can be attributed to the removal of the carbohydrate-rich seed coat. According to Owusu-Kwarteng et al.,[22] during the fermentation process, fermentative microorganisms cause the hydrolysis of proteins and oligosaccharides. Interestingly, carbohydrate content increased in the formulated broths compared to the dehulled fermented *Zamné*, probably due to the contribution of the added ingredients. The carbohydrate content of fermented *Zamné* and formulated broths was higher than those reported by Azokpota et al.,[23] for *Afitin* (13.2%*)*, *Iru* (8.1%) and *Sonru* (9.7%)*,* three different types of condiment produced by fermentation of *Parkia biglobosa* seeds in Benin. Proximate composition of fermented *Zamné* and formulated broths showed these condiments as a good source of nutrients. Tankoano et al.,[2] reported that the development of taste or aroma during fermentation leads to an improvement in the nutritional value of the condiment.

The study provides an overview of consumers' perception of fermented *Zamné*. However, it has limitations. Water activity was not assessed; therefore, microbial shelf stability cannot be established from moisture. Furthermore, the lack of direct profiling of minerals makes it impossible to evaluate *Zamné*'s nutritional contribution in terms of mineral micronutrients. It is also important to note shortcomings related to sensory analysis. The panel sizes were small and predominantly composed of young people, and the consumers were untrained. This makes it difficult to generalize the results. A larger panel size with trained consumers is therefore necessary for a comprehensive assessment. The lack of cost analysis makes it impossible to determine whether the product resulting from the optimized formula will be affordable for consumers. It is therefore important to evaluate the cost associated with the optimization.

CONCLUSION

The present study demonstrated that fermented *Zamné* (*Senegalia macrostachya seeds*) is a nutritionally valuable condiment, rich in protein, lipids, and minerals. Dehulling significantly improved its sensory acceptability, likely by improving the color and reducing undesirable flavor attributes. Furthermore, formulation into broth powders enhanced its consumer acceptability. F5 showed the highest observed sensory acceptability among the tested formulations. These findings highlight the potential of combining processing and formulation approaches to valorize underutilized fermented *zamné* and promote its wider consumption.

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Conflict of interest

The authors do not have any conflict of interest.

Data Availability Statement

This statement does not apply to this article.

Ethics Statement

This study was approved by the Health Research Ethics Committee of the Ministry of Health of Burkina Faso on December 3, 2025, authorization number: 2025-12-541.

Informed Consent Statement

Informed consent was obtained from all the participants (age > 18 years) involved in the study.

Clinical Trial Registration

This research does not involve any clinical trials.

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Not Applicable.

Author Contributions

Anaïs Kady Coulibaly: Conceptualization, Methodology and Original Draft; Henri Sidabéwindin Ouédraogo: Data collection and analysis; Kénan Yidia Kinda: Material preparation; Charles Parkouda: Supervision; Aly Savadogo: Supervision

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