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Nutritious Raw Soumbala Seasoning: An Alternative for Its Valorization and Acceptability

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Authors' contributions

This work was carried out in collaboration among all authors All authors read and approved the final manuscript.

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ABSTRACT

A healthy diet is essential for the prevention of certain diseases. Therefore, it is essential to test the formulation of unprocessed or minimally processed foods. The aim of this study was to formulate a soumbala-based food with high nutritional and nutraceutical potential. Despite its recognised nutritional and nutraceutical importance, the consumption of raw soumbala remains difficult due to certain physico-chemical parameters. Therefore, six spices commonly used by the local population were combined. Standard methods were used to evaluate the physicochemical and biochemical properties of the formulations. The sensory analysis was carried out by a panel of people aged at least 15 years who usually eat soumbala. The experiment produced 17 formulations using Minitab 18 software. The analysis showed that the protein content was (19.23 - 33.30% DM); lipids (19.51 - 27.99% DM); carbohydrates (35.95 - 86.66% DM) and the pH was between 6.37 and 6.88, i.e. slightly acidic. Sensory analysis showed that formulations F06, F05, F10, F13 and F17 were the most popular. In order to increase the value of soumbala, it would be worthwhile to popularise and promote the consumption of these foods.

Keywords: Soumbala; spices; seasoning; formulation; nutritional quality; nutraceutical quality.

1. INTRODUCTION

A healthy balanced diet is a nutritional practice that helps maintain or improve health throughout life. It provides the body with the nutrients it needs for proper functioning. Such diets are essential to prevent non-communicable diseases like diabetes, high blood pressure, and obesity (Zhang et al. 2021). As these diseases become epidemics worldwide, particularly due to an energy-dense, nutrient-poor diet, it is necessary to formulate healthy, nutritious foods that prevent these pathologies (Mondo et al. 2024, Shahidi & Hossain 2022). These formulations must take into account people's preferences and eating habits (Shahidi & Pan 2022). For a sustainable food system, formulations need to give priority to local products that are accessible and low in cost. Non-timber forest products, long considered nutritious by populations, are receiving special attention, particularly in food technology (Ismail 2024). One such food is soumbala. This highly valued food is derived from the alkaline fermentation of *Parkia biglobosa* seeds. In fact, several studies have highlighted the nutritional and nutraceutical importance of soumbala. It has long been recognized as an important source of protein, rich in essential amino acids. It is therefore recommended to alleviate malnutrition. Its pH is slightly basic, which helps preserve the enzymes that facilitate digestion and ensure good digestibility (Ntsame et al. 2011). Soumbala is very rich in potassium and low in sodium, it is considered as a natural hypotensor and is recommended to prevent and/or control high blood pressure (Shahidah et al. 2019, Yamamura et al. 2023). Its low carbohydrate and lipid content helps prevent weight gain, obesity and all its associated pathologies. Other studies have shown that Soumbala contains high levels of bioactive compounds, especially phenolics, vitamins and other antioxidants (Seal et al. 2021). Most of these studies have focused on evaluating soumbala in its raw, uncooked state. In view of all these benefits, the popularization of the consumption of raw soumbala will not only contribute to the reduction of malnutrition, but also to the prevention of a number of non-communicable diseases (Knez et al. 2024). Unfortunately, many consumers are still reluctant to incorporate raw soumbala into their dietary habits. This is due to certain organoleptic properties of soumbala, particularly its flavors. In fact, the fermentation of soumbala leads to the appearance of several properties, including the unpleasant odors perceived by some consumers (Seal et al. 2021).

A food formulation that includes the elimination of these flavors, while preserving the nutritional and nutraceutical quality, is essential for the acceptance of raw soumbala. Formulation of a soumbala-based food with commonly used spices would be welcomed (Ntsame et al. 2011). These include onion, parsley, chili, green anise, guinea pepper, black pepper and a little salt. In this context, this study was initiated to formulate a highly nutritious food based on soumbala and spices commonly used.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Plant materials

Soumbala was produced and sampled in 2023 at Bousséra, Gaoua in southwest Burkina Faso.

These dry samples were packaged in sterile bags, then sent to the laboratory of the Food Technology Department of the Institute for Research in Applied Sciences and Technology (IRSAT) in Bobo-Dioulasso, where they were ground into powder for analysis. The spices were purchased in Bobo-Dioulasso. They were then dried and ground into powder.

2.1.2 Sample collection form

Sampling was carried out according to the sampling guide of the Institute for Research in Applied Sciences and Technology, in accordance with the guidelines of the National Biosafety Agency of Burkina Faso. The study included plants commonly used as spices by the local population, so there was no need for identification or herbarium collection.

2.2 Methods

2.2.1 Physicochemical analysis

The water content of the samples was determined by differential weighing before and after oven drying at 105±2°C for 24 hours of a 5 g sample (Atwater & Rosa 1899).

The pH was determined using a digital pH meter (HI 991300, PH/EC/TDS meter) (ISO_20483 2013).

Acidity was determined by titration using the method described by ISO (2009).

Total sugars were determined by the sulfuric orcinol method described by Montreuil & Spik (1969). Carbohydrate contents were calculated using a calibration curve with D-glucose as the reference sugar.

The fat content of samples was determined by Soxhlet extraction, adapting the international standard ISO-659 with hexane (Montreuil & Spik 1969).

The protein content of the samples was determined using the Kjeldahl method described in Evuen et al. (2022).

The energy value of the samples was calculated using the coefficients of Atwater & Rosa (1899) according to the following formula:

Energy (Kcal/100g) = % carbohydrate × 4 Kcal + % protein × 4 Kcal + % fat × 9 Kcal

2.2.2 Formulation and organoleptic analysis

From the raw material, seventeen (17) formulations were generated using Minitab18 software. The organoleptic analysis was aimed at testing the acceptability and preference of condiments by tasters, in order to select the best formulation. It took place over four sessions. The seventeen formulations generated through the experimental design were divided into three groups. These samples were subjected to hedonic and ranking tests to select the best. The best formulations from each group analyzed were retained to form a final group for selection of the best formula by the tasters. A panel of 35 male and female tasters over the age of 15.

2.3 Statistical Analysis

Formulations were developed using Minitab18 software. For physicochemical analyses, data were entered using Microsoft Excel 2013 and XLSTAT software univariate ANOVA analysis at 5% threshold with adjusted R^2 and principal component analyses. Physicochemical analyses and results are expressed as mean values ± standard deviation. Sensory evaluation test data were entered using Microsoft Excel 2013 and analyzed using SPSS 21 software. Descriptors were converted into numerical notation.

3. RESULTS AND DISCUSSION

3.1 Results

In the process, 17 formulations were developed, ranging from formulation 1 (F01) to formulation 17 (F17). These formulation results are assigned in Table 1.

3.1.1 Results of physicochemical parameters

Table 2 shows the results of the physicochemical analyses of the formulations. Acidity ranged from 2.25 ± 0.05 for F06 to 5.01 ± 0.16 for F01. These differences in acidity would appear to be linked to the physicochemical properties of the different raw materials used. For example, the low acidity of F06 is due to the low proportions of spices, in contrast to F01 (Table 1). Nevertheless, the acidity of a food can be an indicator of its quality, as it can help to preserve it to a greater or lesser extent. The pH of the formulations ranged from 6.37 ± 0.03 for F06 to 6.88 ± 0.01 for F11. Dry matter ranged from 88.07% ± 0.28 for F17 to 93.26% ± 0.17 for F14. Protein contents ranged from 19.23% ± 0.02 for F13 to 33.30% ± 0.03 for

F10. In these formulations, fat contents ranged from 19.51% ± 0.43 for F06 to 27.89% ±0.02 for F05. Carbohydrate values ranged from 35.95%± 0.34 for F10 to 86.66%± 0.00 for F14. The energy values of the different formulas varied significantly between 475.48±2.32 and 639.83±2.24 Kcal/100 g.

3.2 Discussion

The formulations have different pH values. This difference may be linked to the addition of black pepper to the F11 formulation and to processing conditions. which can influence pH levels (Adu et al. 2021). As well as acidity, the pH of these formulations can influence storage stability. The low acidity of these formulations is an asset in preventing gastro-oesophageal reflux disease (GERD) (Wang et al. 2024). Other authors have reported that the optimal pH in a healthy organism varies from 6.1 to 7.5 (Muth & Park 2021).

Analysis of Table 1 suggests that the high dry matter content of the F14 formulation is attributable to the contribution of the various ingredients, but especially the salt, which contains a low water content. Nevertheless, dry matter contents are relatively high in all formulations and could be an indicator of high macronutrient concentration, as well as micronutrient concentration. Their low water content ensures a long shelf-life (Komolafe et al. 2024). Studies have also shown that the mineral content of a food is linked to its dry matter content (ISO 1998).

The high protein content of the F10 formulation may be linked to its high proportion of soumbala. Indeed, studies have reported that soumbala is an important source of protein (Seal et al. 2021). Higher levels of soumbala could not only help combat protein-energy malnutrition, but also positively influence the bioaccessibility of the carotenoids contained in spices (Islam et al. 2021). In addition, proteins facilitate the bioavailability of minerals contained in the various raw materials and formulation components (Puri et al. 2023). Although some report that non-thermal food processing can lead to protein oxidation, the presence of spices rich in bioactive compounds helps to produce a healthy and nutritious food (Puri et al. 2023, Chinma et al. 2023, Agrahar-Murugkar 2020).

Lipids are an important source of energy for the human. They are also a source of essential fatty acids and play a crucial role in the development of flavors and in the transport of fat-soluble bioactive compounds such as vitamins A D E K and carotenoids. The presence of lipids in a food is of great importance, especially plant lipids rich in essential fatty acids (Reynolds et al. 2021). In these formulations, fat contents ranged from 19.51% ± 0.43 for F06 to 27.89% ±0.02 for F05. These high lipid contents can be explained by the high lipid content of soumbala. Thus, formulation F05 containing a high proportion of soumbala (64.06%) is the most concentrated in lipids. These formulations are nutritionally important because, without heat treatment and with the contribution of the spices' antioxidant compounds, their lipids will be protected from any degradation and, above all, will protect the body against certain chronic diseases, notably cardiovascular disease (Aziz et al. 2024, ISO 1989).

Carbohydrate values ranged from 35.95%± 0.34 for F10 to 86.66%± 0.00 for F14. Analysis of variance ANOVA ($P < 0.0001$) indicates that physicochemical characteristics vary according to formulation. These variations could be due to the different proportions of raw materials depending on the formulation. Carbohydrates are the main energy sources used by the body. However, a diet rich in carbohydrates with a high glycemic index can be detrimental to health (Tankoano et al. 2024). These dietary fibre-rich formulations can be an alternative for a balanced, preventive diet (Barber et al. 2021).

The energy values of the different formulas varied significantly. These variations were due to differences in the composition of the raw materials (soumbala and spices) (Table 1). However, these formulated foods remain potential low-cost energy sources, especially for low- and middle-income countries where undernutrition is prevalent. They could also help offset the need for functional foods to prevent certain metabolic diseases such as diabetes, hypertension and obesity (Grootveld et al. 2020). In a context where the consumer's need for plant-based foods is becoming more and more of a requirement, these types of foods should be encouraged and promoted as part of a healthy diet. Priority is indeed given to foods rich in bioactive compounds, but foods that combine the two advantages (nutritional and nutraceutical) would be a considerable asset for consumers, especially athletes (ISO 1991, Alves et al. 2021).

Table 1. Ingredients content of the various formulations

Order Essay	Soumbala (%)	Chili (%)	Parsley (%)	Onion (%)	Guinea pepper (%)	Black pepper (%)	Salt (%)	Green anise (%)	Total
1	51.40	3.00	4.00	11.50	19.00	6.55	2.00	2.55	100,00
2	51.57	15.07	4.06	11.56	6.56	6.56	2.05	2.57	100,00
3	50.00	1.00	2.50	10.00	5.00	5.00	0.50	26.00	100,00
4	53.13	4.13	5.63	13.13	8.13	8.13	3.63	4.13	100.00
5	64.06	2.56	4.06	11.56	6.56	6.56	2.06	2.56	100.00
6	50.00	1.00	2.50	10.00	5.00	5.00	25.50	1.00	100.00
7	50.00	26.00	2.50	10.00	5.00	5.00	0.50	1.00	100.00
8	50.00	1.00	2.50	10.00	30.00	5.00	0.50	1.00	100.00
9	51.56	2.56	16.56	11.56	6.56	6.56	2.06	2.56	100.00
10	75.00	1.00	2.50	10.00	5.00	5.00	0.50	1.00	100.00
11	50.00	1.00	2.50	10.00	5.00	30.00	0.50	1.00	100.00
12	51.56	2.56	4.06	11.56	6.56	6.56	2.06	15.06	100.00
13	51.56	2.56	4.06	24.06	6.56	6.56	2.06	2.56	100.00
14	51.56	2.56	4.06	11.56	6.56	6.56	14.56	2.56	100.00
15	50.00	1.00	27.50	10.00	5.00	5.00	0.50	1.00	100.00
16	51.56	2.56	4.06	11.56	6.56	19.06	2.06	2.56	100.00
17	50.00	1.00	2.50	35.00	5.00	5.00	0.50	1.00	100.00

Table 2. Physicochemical parameters and energy value of the different formulations

	Paramètres physico-chimiques						
Formulations	**Acidity (%)**	**pH**	**DM (%)**	**Protein (% DM)**	**Lipide (% DM)**	**Glucide (% DM)**	**Energy (Kcal /100 g DM)**
F1	5.01±0.16	6.74±0.07	90.71±0.23	27.03±0.07	25.14±0.60	72.80±0.09	625.58±6.04
F2	3.71±0.00	6.67±0 .04	91.26±0.02	26.58±0.01	23.95±0.11	78.78±1.04	636.99±5.19
F3	3.00±0.00	6.78±0.01	92.32±0.25	26.09±0.07	26.65±0.47	54.99±0.51	564.17±6.55
F4	3.20±0.05	6.64±00	91.32±0.01	28.11±0.00	25.46±0.34	69.57±0.11	619.86±3.5
F5	2.84±0.11	6.63±0.00	90.39±0.18	29.12±0.06	27.89±0.02	38.80±2.58	522.69±10.74
F6	2.25±0.05	6.37±0.03	92.39±0.26	23.19±0.06	19.51±0.43	70.80±0.58	551.55±6.43
F7	3.31±0.00	6.76±0.04	91.40±0.07	26.25±0.02	24.64±0.14	47.93±0.24	518.48±2.3
F8	2.56±0.05	6.71±0.07	88.65±0.07	26.21±0.02	25.97±0.07	58.77±0.79	573.65±3.87
F9	3.24±0.00	6.61± 0.00	90.11±0.15	25.15±0.04	26.56±0.21	65.07±5.72	599.92±24.93
F10	3.16±0.00	6.73±0.01	88.77±0.07	33.30±0.03	25.23±0.19	35.95±0.34	504.07±3.19

	Paramètres physico-chimiques						
Formulations	**Acidity (%)**	**pH**	**DM (%)**	**Protein (% DM)**	**Lipide (% DM)**	**Glucide (% DM)**	**Energy (Kcal /100 g DM)**
F11	2.92±0.00	6.88±0.01	91.08±0.09	25.28±0.03	23.69±0.32	81.86±0.32	641.77±4.28
F12	3.32±0.56	6.66±0.02	91.02±0.08	27.29±0.02	26.17±0.14	51.56±0.43	550.93±3.06
F13	3.16±0.00	6.64±0.03	90.56±0.11	19.23±0.02	24.03±0.24	86.66±0.00	639.83±2.24
F14	3.04±0.06	6.50±0.00	93.26±0.17	26.81±0.05	22.96±0.20	40.40±0.08	475.48±2.32
F15	3.28±0.06	6.75±0.02	91.77±0.09	26.35±0.03	23.38±0.50	51.53±1.04	521.94±8.78
F16	2.84±0.11	6.76±0.06	92.33±0.18	25.47±0.05	23.74±0.11	49.33±0.03	512.86±1.31
F17	4.22±0.16	6.62±0.00	88.07±0.28	25.25±0.08	20.40±0.52	54.35±0.63	502±7.52
R^2	0.97	0.96	0.99	1.00	0.99	1.00	1.00
p value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Legend : p-value indicates statistically significant difference.

3.2.1 Principal component analysis

Analysis of the correlation between the various parameters showed a positive correlation between acidity and all other parameters except dry matter (Fig. 1). This correlation is even stronger between acidity and pH, implying that pH is partly influenced by the various organic acids. Thus, the higher the acidity, the lower the pH. This correlation between pH and titratable acidity has been demonstrated by other authors, who report that certain organic acids may not be taken into account when measuring pH (Smiechowska et al. 2021). There was also a negative correlation between titratable acidity and dry matter. This shows that titratable acidity depends on the moisture content of the feed and also on the contribution of soumbala, which is slightly alkaline, Furthermore, the most significant negative correlation is that between proteins and carbohydrates. This correlation could be due to soumbala, which is partially digested by microorganisms. Studies have shown that proteins can form complexes with carbohydrates, reducing their digestibility (Bhatta et al. 2020). On the other hand, the highest positive correlation is between carbohydrates and energy value. This means that carbohydrate-rich formulations are low in protein. This could be explained by the fact that carbohydrates are the main sources of energy. In a healthy diet, 55-75% of human energy is provided by carbohydrates (Barbhuiya et al. 2021).

Principal component analysis shows that the parameters studied can be represented on two axis (61.1% of total inertia) (Fig. 2). The information in Fig. 2 shows that formulations F01, F02 and F11 are rich in protein, carbohydrates, fat and energy, and have a high acidity. Formulations F05, F07, F10; F12 and F14 are low in protein, carbohydrates, fat and energy. In addition, formulations F06, F16 and F14 are rich in dry matter and have a low pH. These differences in the content of the various formulations depend on the raw materials used, in particular the proportions assigned to them (Table 1).

3.2.2 Sensory analysis and classification of formulations

To facilitate the acceptability of food. consumers must be associated to take into account their needs and preferences (Shahidi & Pan 2022). For this study; panels of tasters were set up to assess the organoleptic quality of the various formulated foods. The results of these sensory analyses are classified into three groups according to the hedonic test in the figures (Figs. 3-5).

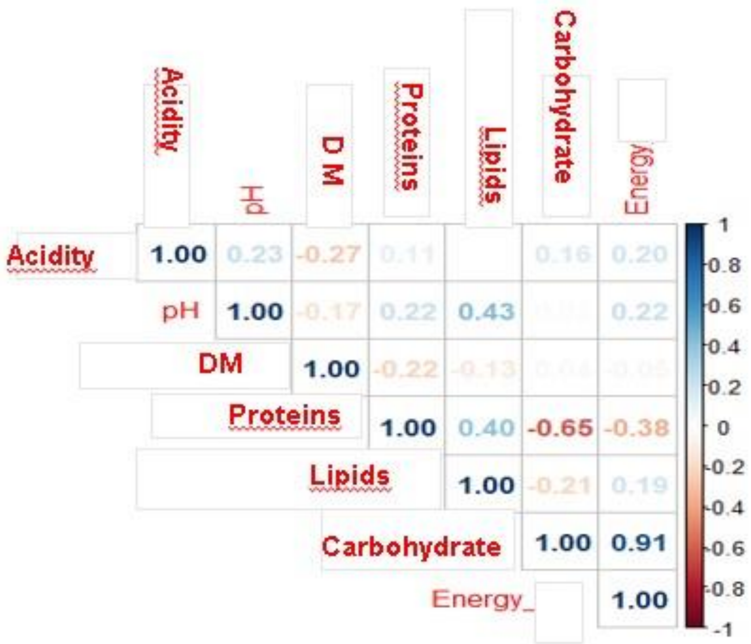

Fig. 1. correlation between the studied parameters

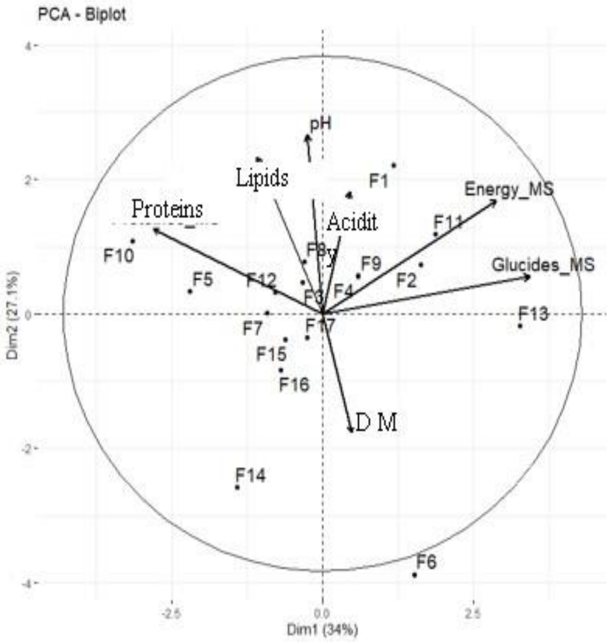

Fig. 2. Principal component analysis between parameters and formulations

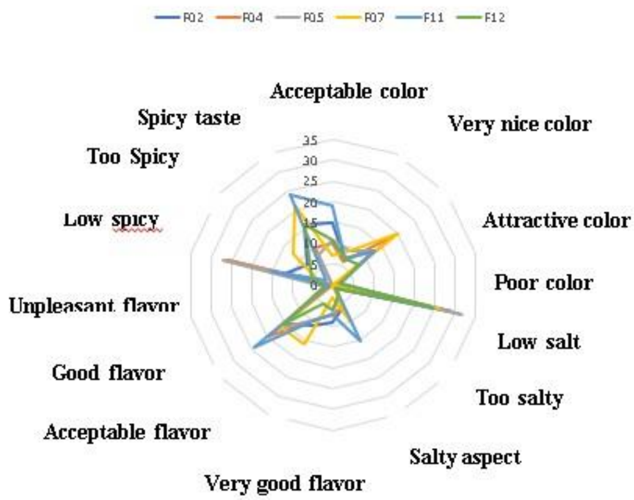

Fig. 3. Sensory analysis of Group 1

Fig. 3 shows the sensory analysis test for group 1. In general, all the formulations in this group were rated according to the sensory characteristics of color, taste (salty and pungent) and odor. However, the most appreciated were F05, followed by F11 and F07. The proportions of tasters who rated the taste of F05 as not very pungent were 77% and 91.42% respectively. This would be due to the contribution of onions and peppers. Meanwhile, 71% of tasters rated the taste of F11 as pungent, 71.42% as not very salty, 54.28% as acceptable in color and 71% as having a good odor. These organoleptic characteristics could be due to the low proportion of salt and the high proportion of hot pepper. For F07, 60% of tasters judged the taste to be pungent; 45.71% acceptable odor and 57.14% good color. This could be due to the contribution of salt, black pepper and the average proportion of soumbala (50%).

For Group 2 (Fig. 4), tasters preferred the F06, F17 and F15 formulations with different proportions. Thus, for F06, 94.28% found the taste not very pungent, while 45.71% found it salty and 34.28% a very nice color. An analysis of the raw materials composition table reveals that this formulation contains a high proportion of salt and onion, which could justify the tasters' assessment. For F17, 68.57% of tasters rated the taste as not very pungent, 80% as not very salty, 40% as having a good color and 31.42% as having a good odor. In this formulation, it was the high proportion of onion and the low proportion of salt that would have guided tasters' perceptions. As for formulation F15, the proportions were: 85.71% judged not very pungent; 88.57% not very salty; 37.14% good odor and 34.28 % acceptable color. It's also important to note that all formulations were positively appreciated by tasters with varying preferences. Parsley, onion and low salt content are the main characteristics that differentiate this formulation.

All the formulations in Group 3 were appreciated to varying degrees by the tasters (Fig. 5). In fact, F10 was the most appreciated. with 94.28% of tasters rating the taste as not very spicy, 94.28% as not very salty, 60% as very good in color and 48.57% as good smelling. This formulation was mainly characterized by a high proportion of soumbala (75%), a medium concentration of onion (10%) and a low salt content (0.5%). After F10, F13 was also positively appreciated. Many tasters (62.85%) rated the taste as not very pungent, 74.28% as not very salty, 40% as having a good color and 40% as having a good smell. Although preferences depend on each individual, these assessments could be based on an average intake of soumbala (51.56%), but especially a high intake of onion (24%).

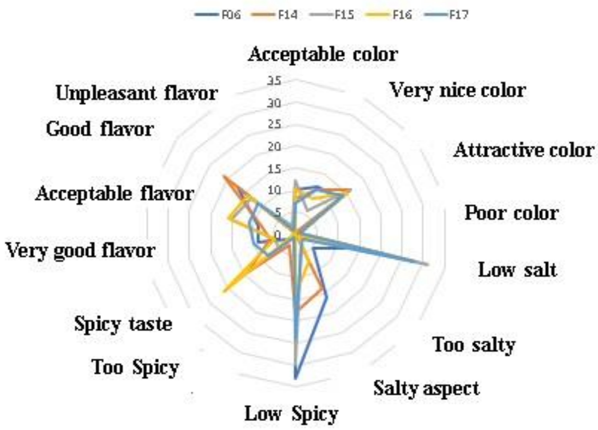

Fig. 4. Sensory analysis of Group 2

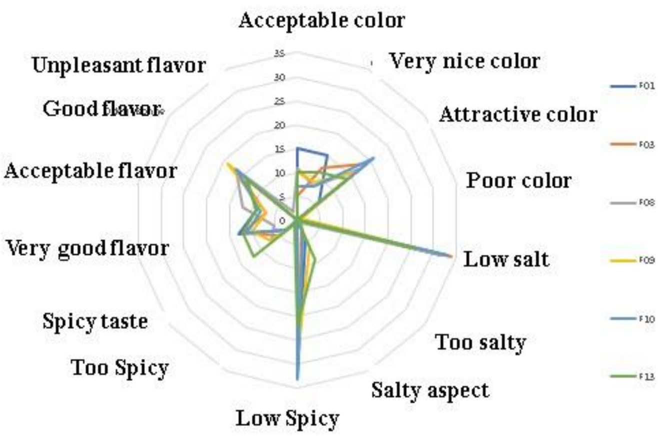

Fig. 5. Sensory analysis of Group 3

Following the tasting session, the different formulations were evaluated by all the tasters and subsequently ranked according to their preferences. Following the ranking procedure, six formulations were identified as the most popular. The results of these rankings were then subjected to statistical analysis to ascertain the nature of the correlations that exist in the six most highly rated formulations (Figs. 6-7). Fig. 6 illustrates that the tasters' selections can be categorized into two principal groups, which are themselves subdivided into subgroups. It is evident from this figure that tasters who appreciate the color are more or less drawn to formulations with lower salt and spice levels. Conversely, those who appreciate the aroma are more or less associated with saltier and spicier formulations.

The principal component analysis also divides the six formulations into two groups according to their similarity (Fig. 7). Formulations F06, F13, and F17 are positively correlated with one another. This positive correlation is likely attributable to the similar proportions of spices utilized in each formulation (Table 1) (Monterrosa et al. 2020). In addition, formulations F05, F07, and F10 are also positively correlated with one another. The observed similarity in organoleptic parameters is attributable to the spices, except chili pepper (Table 1).

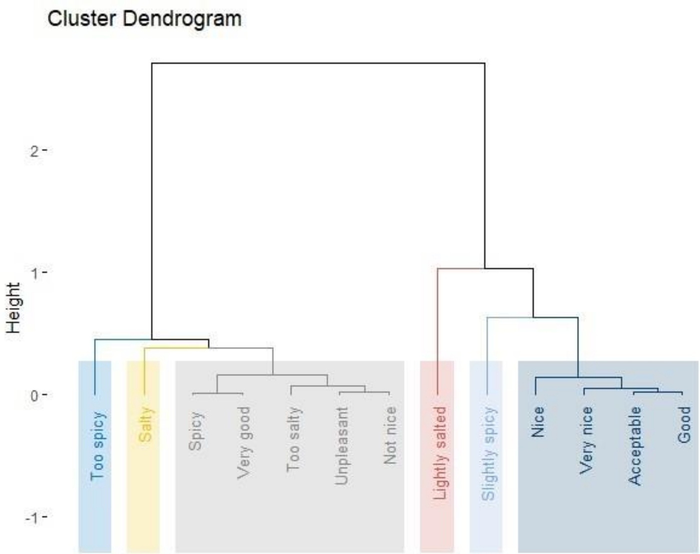

Fig. 6. Dendrogram of sensory parameters

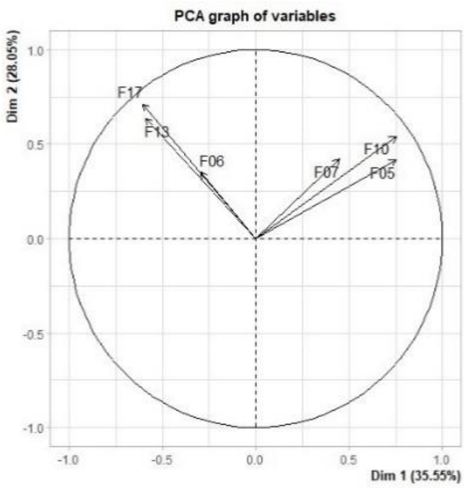

Fig. 7. Principal component analysis of different formulations

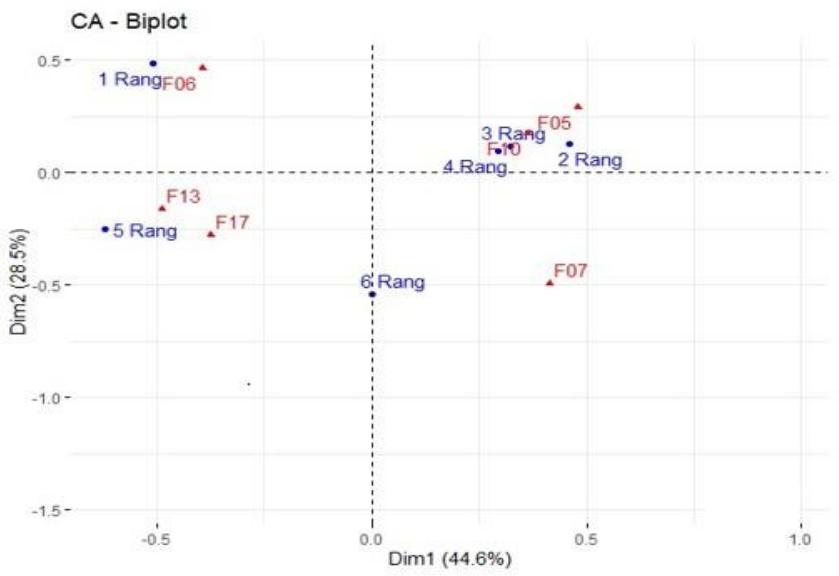

Fig. 8. Classification of the most popular formulations according to tasters' preferences

Fig. 8 illustrates the statistical ranking of the most highly rated formulations. The data indicate that formulation F06, which contains the highest concentration of salt, is ranked first, followed by formulation F05. These findings suggest that tasters may have disparate perceptions of quality based on their sensory experiences. For F06, the choice is mainly motivated by its salt content, to compensate for the glutamate contained in the cubes. Nevertheless, it should be eaten in moderation, and should be avoided whenever possible by people with high blood pressure, as salt intake is an essential factor in the onset of blood pressure attacks (Lin et al. 2020). For this population, formulations with lower salt levels may be more beneficial in reducing blood pressure fluctuation (Lin et al. 2020).

On the basis of these rankings and the physicochemical analysis, certain formulations were selected as best formulations, taking into account the proportions in which they were appreciated by tasters. It should be noted that F10 has a clear advantage, as it contains a high proportion of soumbala in addition to onion and parsley, with a very low salt content (0.5%). After F10, formula F05 has the highest soumbala content with medium proportions of spices.

4. CONCLUSION

The study involved the development and production of seventeen condiment formulations based on soumbala powder, using Minitab18 software. The results of the physicochemical and sensory analyses show that the condiments formulated are a good source of protein, lipids, and carbohydrates. Sensory analysis of the seventeen formulations revealed that they were all acceptable, although formulations F05, F06 and F10 were the most appreciated. To enhance the value of soumbala and spices, it would be interesting to diversify the forms of consumption and raise consumer awareness of its nutritional value. Nevertheless, it is suggested that the mineral content and nutraceutical potential of these formulations be evaluated.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT. COPILOT. etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

CONSENT AND ETHICAL APPROVAL

Each participant gave informed consent by completing the form provided by the Burkina Faso Applied Sciences and Technology Research Institute (IRSAT).

Prior to completing the participation form, participants under 18 years of age had to obtain the consent of their parents or guardians. Informed consent is non-binding.

All personal data is treated confidentially and is not disclosed without written consent.

The consent form is available on request from the corresponding author.

The ethics committee of the Institute for Research in Applied Sciences and Technology has given a favourable opinion for this work to be carried out.

DATA AVAILABILITY STATEMENT

Study data are available from the corresponding author for researchers upon request.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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