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Nutritional and Sensory Characteristics of Spices Based on Local Ingredients Formulated by the Design of Experiments Methodology

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Abstract

A spice formulation study in Burkina Faso was carried out using local ingredients for the benefit of households. The objective of this study was to propose some spice formulations based on local ingredients in order to reduce the use of chemical spices in the preparation of different dishes. The Design of Experiments (DOE) methodology was used for the formulation of the spices and their physicochemical, nutritional and sensory characteristics were evaluated by standardized and standard methods. The results obtained showed lipid contents (g/100 g DM) ranging from 10.41 ± 0.26 to 15.64 ± 0.68, total sugars from 4.39 ± 0.32 to 5.46 ± 0.31, protein from 3.65 ± 0.17 to 12.04 ± 0.35 and ash from 5.83 ± 0.01 to 7.02 ± 0.01. The polyphenol content ranged from 9.09 ± 1.60 to 11.33 ± 0.90, and the flavonoid content ranged from 0.65 ± 0.03 to 1.08 ± 0.13. The sensory analysis carried out showed that the spices have generally satisfactory organoleptic characteristics. These results constitute new information in the diet of populations and are an alternative to the chemical spices used in their cooking.

Keywords

Formulation, Spices, Design of Experiment, Biochemical Characteristics

1. Introduction

Spices have played an essential role in the cuisine of the population since ancient times. They are appreciated for their antiseptic and preservative properties [1]. Known for the taste and fragrance they bring to food dishes, spices go beyond these culinary values, for therapeutic virtues. Some spices contain nutrients and bioactive compounds that influence the functioning of the body [2] [3].

In sub-Saharan Africa, it was Indian traders who introduced spices, first to East Africa in the 3rd century BC where they established a clove trading center on the island of Zanzibar [4]. Spices are used to prepare foods mainly because of their flavoring, organoleptic and medicinal properties [5].

In Burkina Faso, cooking enthusiasts use spices a lot in their preparation. Indeed, many research studies have shown the use of spices in the formulation of the coating sauce for dried meat strips in the production of Kilishi [6]. Spices include ginger, cloves, black pepper, guinea pepper, red chili pepper, and fake nutmeg. Most of these spices and ingredients that make up the sauce for coating meat strips are available on West African markets and are used in the seasonings of grilled meats prized by these populations [7]. Spices could be used to produce cured meats that meet the culinary and cultural habits of Burkinabe consumers at low cost [6]. Formulation is a complex process that takes into account several factors, including the rate and threshold of ingredient incorporation, the manufacturing process, and consumer eating habits. The design of experiments method is a statistical tool that is well suited to the food formulation process. It makes it possible to highlight the effects of each ingredient on the quality of the product [8]. Despite the importance of this method, its application is limited in the production of spice blends. In order to improve the formulation of spices used in culinary preparations in Burkina Faso, the present study was conducted.

2. Materials and methods

2.1. Plant Material

The plant material in this survey consists of samples of pepper, fake, garlic, anise, nutmeg and ginger. These raw materials have been selected on the basis of availability, accessibility, and their organoleptic characteristics.

2.2. Methods

2.2.1. Formulation

The spice formulation was carried out using the design of experiments method, including the mixing design, using Minitab software version 21.3.

Six raw materials were selected as factors in the study. These are pepper, fêfê, garlic, anise, nutmeg and ginger. The level of these factors was set by the method developed by Cornell [9] and Tinsson [10]. The method consisted of varying the proportion of the constituents so that the sum is equal to one hundred (100).

The experiment matrix was constructed with Minitab software version 21.3 according to the method developed by Scheffe [11] and Piepel [12] using the Simplex Lattice Design with an m = 1 mesh. This matrix is a set of combinations of modalities for each factor used in the test [10]. A series of six feed formulas were generated with the criteria selected in the software. The top tier of each constituent was combined with the bottom tier of the other five (5) constituents. **Table 1** presents the series of six formulas generated. These formulas have been codified from F1 to F6.

Table 1. Formulation matrix.

Order essay	Pepper	Cubeb pepper	Garlic	Anise	Nutmeg	Ginger
F1	23	25	15	15	10	12
F2	10	38	15	15	10	12
F3	10	25	28	15	10	12
F4	10	25	15	28	10	12
F5	10	25	15	15	23	12
F6	10	25	15	15	10	25

2.2.2. Physico-Chemical Analysis

Moisture and dry matter were determined by drying in the oven [13]. The total ash was determined by incineration at 550˚C for 4 hours in a muffle furnace according to the standard **ISO standard 2171** [14]. The determination of total sugars is carried out by the Phenol-sulphuric acid method described by Dubois *et al*., (1956) [15]. The protein content was determined by the Bradfort method (Bradfort, 1976) [16]. The fat was determined by **ISO 659** [17]. Total phenolic compounds were determined according to the procedure described by **Singleton and Rossi** [18]. The total flavonoid contents of the extracts were determined by Dowd's colorimetric method adapted by **Arvouet-Grand *et al.*** [19]. The reducing power was determined by the FRAP method developed by **Benzie and strain** [20] read at an absorbance of 700 nm [21]. Free radical free radical activity was determined by the DPPH method [22].

2.2.3. Sensory Analyses

Two sensory tests were performed: the sensory profile and the hedonic test. Six (06) samples of spice blends were subjected to the hedonic test and sensory profile. Sensory attributes such as color (determined from the spice powder), aroma and texture were tested on the powder of the different spices. The flavor was tested by making a 1-liter meat broth for each sample, to which we added three (03) grams of salt and one (01) gram of spice. The acceptability of the samples was assessed by the hedonic assay.

❖ **The tasting panel**

The sensory analysis method consisted of choosing a panel, coding samples, preparing these samples and performing the test itself.

A panel of 30 tasters was selected to carry out the test. It was made up of 40 % men and 60 % women over the age of 15.

❖ **Sample coding**

Samples were coded using three-digit codes (**Table 2**). These codes were chosen using random tables of numbers [23]. Codes were assigned to samples and combined with each other.

Table 2. Sample coding.

Samples	Three-digit codes
EE1	976
EE2	834
EE3	500
EE4	152
EE5	453
EE6	835

❖ **Sample preparation**

The samples that were the subject of the various sensory tests were prepared by mixing under the same conditions in order to limit changes within the products. They were put in clear tasting jars and placed on trays by combination.

❖ **The sensory test**

The 30 tasters received information about filling in the forms. They were invited to assess the samples on the evaluation sheet. Each taster received a tray with two combinations. The samples were placed in individual voting booths with a sachet of water for rinsing the mouth between two samples, three (03) disposable spoons, a tissue and two (02) evaluation sheets. The samples were presented simultaneously and the taster expressed his opinion. The cards were removed at the end of the tasting and the data was organized and processed. The tasting sheets have been designed according to the sensory tests to be carried out.

3. Statistical Analysis

The taste test data was analyzed using the SPSS 21 software. For this purpose, the descriptors were converted into numerical notation in an Excel 2013 spreadsheet.

For the hedonic test, the descriptors have been converted into numerical notations: 1, 2, 3, 4, and 5 corresponding respectively to **I don't like at all, I like a little, indifferent, I like and I like a lot.**

4. Results

Table 3 presents the results of the biochemical analyses of the different spice formulations. Moisture levels (m/m) ranged from 4.16 ± 0.17 (EE6) to 4.83 ± 0.50 (EE5) with a mean of 4.49 ± 0.28. Protein contents (mg EBSA/100 mg DM) ranged from 3.65 ± 0.17 (EE3) to 12.04 ± 0.35 (EE1) with a mean of 5.60 ± 2.15. The proportions ((mg EG/100 mg DM)) of total sugars ranged from 4.39 ± 0.32 (EE4) to 5.46 ± 0.31 (EE3) with a mean of 4.95 ± 0.32. Lipid contents (m/m/DM) ranged from 10.41 ± 0.26 (EE6) to 15.64 ± 0.68 (EE4) with a mean of 12.38 ± 1.88. The proportions of total ash ((m/m/DM) ranged from 5.83 ± 0.01 (EE5) to 7.02 ± 0.01

Table 3. Physicochemical and antioxidant characteristics.

Samples	Humidity (m/m)	Protein totals (mg EBSA/100 g MS)	Sugars totals (mg EG/100 g MS)	Lipids (m/m)	Ash (m/m)	Polyphenols (mg EAG/100 g MS)	Flavonoids (mg EQ/100 g MS)	FRAP (mg EAA/100 g MS)	DPPH
EE1	4.66 ± 0.34	12.04 ± 0.35	4.54 ± 0.40	10.91 ± 0.33	6.22 ± 0.03	10.05 ± 1.26	1.08 ± 0.13	1.47 ± 0.03	49.49 ± 2.04
EE2	4.82 ± 0.18	3.95 ± 0.07	5.10 ± 0.26	14.75 ± 0.03	5.94 ± 0.03	9.18 ± 0.95	0.81 ± 0.10	1.55 ± 0.09	53.91 ± 6.69
EE3	4.32 ± 0.00	3.66 ± 0.17	5.47 ± 0.31	11.17 ± 0.04	6.31 ± 0.01	9.09 ± 1.60	0.65 ± 0.03	1.45 ± 0.01	74.15 ± 6.24
EE4	4.17 ± 0.50	4.47 ± 0.08	4.39 ± 0.32	15.65 ± 0.68	6.72 ± 0.02	11.33 ± 0.90	0.88 ± 0.09	2.56 ± 0.02	77.55 ± 1.70
EE5	4.83 ± 0.50	4.03 ± 0.13	4.99 ± 0.35	11.40 ± 0.36	5.83 ± 0.01	10.79 ± 1.07	0.66 ± 0.13	3.00 ± 0.08	64.03 ± 7.99
EE6	4.16 ± 0.17	5.44 ± 0.03	5.20 ± 0.13	10.41 ± 0.26	7.02 ± 0.01	10.57 ± 1.29	0.78 ± 0.04	4.54 ± 0.16	89.46 ± 1.25

(EE6) with a mean of 6.34 ± 0.35. Total polyphenol concentrations (mg EAG/100 mg DM) ranged from 9.09 ± 1.60 (EE3) to 11.33 ± 0.90 (EE4) with a mean of 10.17 ± 0.73. Flavonoid concentrations (mg EQ/100 mg DM) range from 0.65 ± 0.03 (EE3) to 1.08 ± 0.13 (EE1) with a mean of 0.81 ± 0.11. The reducing power (mg EAA/100 mg DM) ranged from 1.45 ± 0.01 (EE3) to 4.54 ± 0.16 (EE6) with a mean of 2.43 ± 0.94. Free radical free radical activity profiles ranged from 49.49% ± 2.04% (EE1) to 89.46% ± 1.25% (EE6) with a mean of 68.10% ± 12.29%.

Table 4 shows the sensory characteristics of spices. Three percent (3.3%) of the panel found the color of EE1 and EE4 less beautiful while 76.7% found the color of EE2 spice beautiful. The tasting panel recognized a pleasant aroma at 56.7% for the EE2 sample and 63.3% for the EE5 sample. The flavor was found to be unpleasant for the EE3, EE4 and EE6 samples by 3.3% of the panel while it was pleasant at 53.3% for the EE1 sample. The results indicate that 3.3% of the panel found the EE4, EE5 and EE6 samples to be very fine while 60 % found the EE1 sample to be moderately grainy.

Table 4. Sensory characteristics of sample.

Descriptors	976	834	500	152	453	835
Color Description						
Not beautiful	0	0	0	0	0	0
Less beautiful	3.3	3	0	3.3	0	0
Quite beautiful	23.3	10	20	20	30	13.3
Good looking	56.7	76.7	53.3	63.3	60	66.7
Very beautiful	16.7	10	26.7	13.3	10	10
Aroma description						
Not pleasant	3.3	0	3.3	3.3	0	3.3
Less pleasant	3.3	6.7	0	0	10	6.7
Quite pleasant	30	30	33.3	43.3	13.3	13.3
Pleasant	26.7	46.7	46.7	43.3	63.3	56.7
Very pleasant	36.7	16.7	16.7	10	13.3	20

Continued

Flavor Description						
Disagreeable	0	0	3.3	3.3	0	3.3
Less pleasant	3.3	16.7	6.7	13.3	13.3	20
Quite pleasant	13.3	30	30	13.3	26.7	30
Pleasant	53.3	46.7	50	46.7	46.7	30
Very pleasant	30	6.7	10	23.3	13.3	16.7
Texture Description						
Very fine	0	0	0	3.3	3.3	3.3
End	10	20	30	23.3	20	33.3
Medium-grainy	60	43.3	43.3	36.7	40	36.7
Grainy	16.7	36.7	23.3	30	30	23.3
Very grainy	13.3	0	3.3	6.7	6.7	3.3

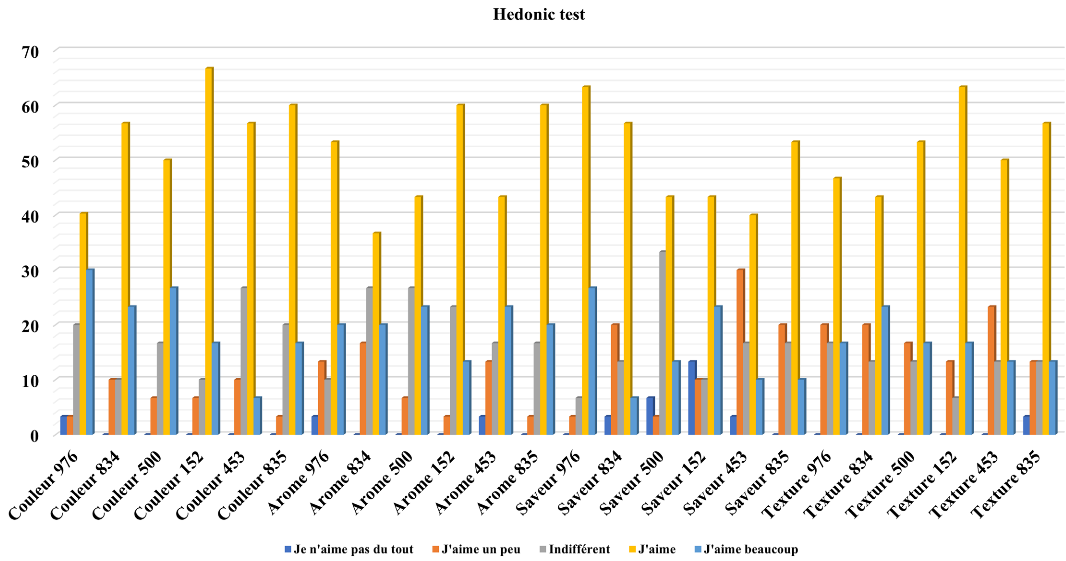

Figure 1. Hedonic characteristics of samples.

Figure 1 shows the hedonic characteristics of the different spice formulas. It states that the highest-scoring trait is the 'like' character for the colour of the EE4 sample, for the aroma of the EE4 and EE6 samples, for the flavour of the EE1 sample, and for the texture of the EE4 sample.

5. Discussion

Analyses for the determination of the moisture content of the spice extracts reveal that the EE6 sample has the lowest value (4.16% ± 0.17%). **Tioursi *et al.*** [24] **and Zaki *et al.*** [25] demonstrated that moisture levels range from 8.1 to 10.03 for dried chili peppers. **Compaore *et al.*** [26] showed that the moisture content of dried plain onions is in the range of 8.36% to 9.24% and 7.92% to 8.52% for dried onions pretreated with salt. The humidity level is very important because it ensures mold-free storage. In short, the low water content of our samples is favorable for good conservation, and a low water content represents an inhibiting factor for the development of microorganisms.

The highest protein content is found in EE1 (12.04 ± 0.35 mg/100 mg DM). **Compaore *et al.*** [26] showed that dried plain onions have a protein content of 6.84%, our results are slightly lower than his.

Total carbohydrate levels varied from sample to sample. The highest content is found in EE6 (5.47 ± 0.31 mg EG/100 mg DM). This value is lower than the values of 49.49% for dried onion powder, 46.64% for onion pretreated with salt 5%, 45.92% for onion pretreated with salt 10% in the study carried out by **Compaore *et al.*** [26]. **Tchiégang *et al.*** [27] observed carbohydrate levels ranging from 4.61% ± 0.04% for *F. leprierii* to 71.75 ± 1.40% for *S. zenkeri* (fruit). In the Zingiberaceae, the total carbohydrate contents are quite distinct: *Aframomum sp* (47.27% ± 0.03%) and *Aframomum daniellii* (39.72% ± 0.34%). *P. guineense* and *P. capense* (Piperaceae), which have 10.24% ± 0.13% and 41.46% ± 0.06% total carbohydrates, respectively, differ significantly at the 5% threshold. The Caesalpiniaceae, S. *zenkeri* (bark) and S. *Zenkeri* (fruit) have distinct total carbohydrate levels that are 16.57% ± 1.02% and 71.75% ± 1.40%, respectively. These results are superior to ours.

The highest lipid content is found at EE4 (15.65 ± 0.68 (m/m)). The levels found vary greatly when moving from one extract to another. These results are much higher than those found by **Amani *et al.*** [28] on the analysis of the physicochemical characteristics of ginger starch, which was 0.1, and those of **Compaore *et al.*** [26] which demonstrated that plain dried onion contains 0.61 % fat.

The highest total ash contents are found in EE6 (7.02 ± 0.01 (m/m)). These results are lower than those found by **Tchiégang *et al.*** [27] in *P. capense* 9.20% ± 0.04% DM, *S. zenkeri* (bark), 9.04% ± 0.16% DM, *H. gabonii* (bark) 8.72 ± 0.37 % DM. On the other hand, they are higher than the ash contents of *H. gabonii* (fruit) 2.01% ± 0.14% DM, *M. myristica* 2.21% ± 0.17% DM, *S. zenkeri* (fruit) 2.50 ± 0.01% DM, which are spices used in the preparation of no poh and Nkui of western Cameroon. Our results are similar to those found by **Zaki *et al.*** [25]**,** which are 6.43%, 7.92%, and 6.86% respectively for paprika from *Tadla, El Kalaa des Sradhna and El Gharb*. The values obtained in the present study are slightly higher than those of the FAO but below the maximum value of 10 % allowed by the ISO 7540 standards.

The EE4 sample had the highest total polyphenol content. This may be due to the high amount of anise it contains, as anise is one of the spices with a high phenolic compound content **Benderradji *et al.*** [29] and **Il-Suk *et al.*** [30] also reported that turmeric is the richest in polyphenols at 67.9 mg/g ES, followed by green anise, nutmeg, ginger, cinnamon, cumin, caraway, fennel, coriander and black pepper. **Maizure** [31] reported that ginger is richer in polyphenols than turmeric. Also, the study by **Kim *et al.*** [32] on a set of spices, showed that coriander is the richest in polyphenols, followed by caraway, turmeric, fennel and cumin.

The flavonoid concentration is higher in the EE1 sample (1.08 ± 0.13 mg EQ/100 mg DM) but less important in the EE3 sample (0.65 ± 0.03 mg EQ/100 mg DM). The high amount of flavonoid in the EE1 sample may be due to nutmeg powder. Indeed, **Annou** [33] showed that the contents of nutmeg are lower in flavonoid than turmeric and caraway, but remain higher than those of other spices. The low flavonoid content of the EE3 sample could be explained by the higher rate of incorporation of cubeb pepper.

The EE6, EE5 and EE4 samples have a high reducing power while EE2 have a low reducing power. The reducing power of EE6 and EE5 can be explained by the presence of nutmeg in the EE5 sample, and ginger in the EE6 sample, all in large quantities compared to the others. Indeed, **Atti** [34] demonstrated in the evaluation of the antioxidant and anti-free radical activities of a spice mixture, that only ginger, rosehip and nutmeg show greater absorbances than controls. On the other hand, the antioxidant activity of different spices could be linked to their richness in polyphenols [35]**.** Indeed, these extracts, rich in total polyphenols, particularly flavonoids, play a very important role in the chelation of transition metals, in this case Fe^{3+} [36]. Many authors and a few previous studies have also shown that the reducing power (reducing capacity) of a compound can serve as a significant indicator of its potential antioxidant activity [37].

The anti-free radical activity profiles obtained reveal that the EE6 sample exhibited the highest anti-free radical activity, possibly due to the high amount of ginger in its mixture, followed by the EE4 sample, which has a higher amount of green anise than the other samples, and EE3. Indeed, **Msaada *et al.*** [38], **Wojdylo *et al.*** [39] and **Mujeeb *et al.*** [40] showed that green anise, coriander, caraway, ginger have a strong antioxidant activity in the DPPH assay with IC50s of 114 ± 0.01; 36 ± 3.22; 153 ± 2.3; 24.97 ± 0.03 µg/ml respectively. The lowest DPPH anti-free radical activities are shown by the EE5, EE2 and EE1 extracts. The difference in results can be explained by the great variability of spices in terms of quality. Moreover, antioxidant activity also depends on the structure and nature of the antioxidants [41].

The tasting panel found the spice colour EE2 and EE6 “beautiful”. This could be explained by the amount of cubeb pepper in the EE2 sample, which gives it a slightly darker color, and the large amount of ginger in the EE6 sample that gives it a lighter color. On the other hand, the EE1 and EE4 spices were considered less beautiful. These results are explained by the high amount of black pepper, cubeb pepper and anise in these samples. The tasting panel found the aroma to be pleasing for the EE5 and EE2 sample. This choice is explained by the fact that there is a higher quantity of nutmeg in the EE5 sample than the other samples, and the same is true for the quantity of ginger in the EE6 sample. We therefore conclude that nutmeg and ginger have a strong and pleasant scent. The flavor is found to be pleasing for most samples especially the EE1, EE2, EE4, and EE5 sample. On the other hand, 20 % of the panel found the flavour to be less pleasant for the EE6 sample, and 16.7 % for the EE2 sample. As for the texture, 60 % of the panel found the samples to be moderately grainy. This may be due to the size of the meshes used to sift the spices.

The hedonic test indicates that the highest rated trait is the "like" character for the colour of the EE4 sample, for the aroma of the EE4 and EE6 samples, for the flavour of the EE1 sample, and for the texture of the EE4 sample.

6. Conclusions

This study has made it possible to know the importance of spices in gastronomy, thanks to their biochemical composition. The spices that make up this mixture are: black pepper, cubeb pepper (or fèfè), garlic, green anise, nutmeg and ginger. The physicochemical analysis revealed the presence of large quantities of lipids in the EE4 sample, protein in EE1, ash in EE6, as well as some secondary metabolites such as polyphenols in EE4, and flavonoids in EE1. Both DPPH and FRAP tests showed strong antioxidant activity in the EE6 sample for DPPH, and in EE6 for FRAP.

This diversity of compounds and secondary metabolites would contribute to the constitution of a mixture combining the organoleptic and even therapeutic qualities of the different spices.

The synergy of metabolites and antioxidant activities of the extract mixtures is studied in order to choose the best formulation in terms of physico-chemical and nutritional quality.

The determination of the sensory properties namely color, aroma, flavor and texture revealed that sample 152 has the most liked color and 976 the least liked; samples 132 and 835 have the most appreciated aroma, 500 and 453 the least appreciated; 976 has the best flavor and 152 has the best texture. The sensory analysis carried out showed that the organoleptic characteristics of the spices were satisfactory for the panel of tasters used. This could be verified by using a larger panel in future studies.

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Authors' Contributions

All authors contributed to the study's conception and design. Inoussa KY wrote the first draft of the manuscript, and all authors reviewed and edited it. All authors read and approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Ito, K.A. (2009) Food Safety Issues and the Microbiology of Spices and Herbs. In: Heredia, N., Wesley, I. and García, S., Eds., *Microbiologically Safe Foods*, John Wiley & Sons, 337-352.

[2] Bellisle, F., Diplock, A.T., Hornstra, G., Koletzko, B. and Roberfroid, M.B. (1998) Functional Food Science in Europe. *British Journal of Nutrition*, **80**, S1-S193.

[3] Riedl, K.M., Carando, S., Alessio, H.M., McCarthy, M. and Hagerman, A.E. (2002) Antioxidant Activity of Tannins and Tannin-Protein Complexes: Assessment *in Vitro* and *in Vivo*. *ACS Symposium Series*, **807**, 188-200. https://doi.org/10.1021/bk-2002-0807.ch014

[4] Raghavan, S. (2007) Handbook of Spices, Seasonings, and Flavorings. 2nd Edition, CRC Press.

[5] Banerjee, M. and Sarkar, P.K. (2003) Microbiological Quality of Some Retail Spices in India. *Food Research International*, **36**, 469-474. https://doi.org/10.1016/s0963-9969(02)00194-1

[6] Tiendrebeogo, S.C.W., Kabore, D., Tankoano, A., Pare, A., Hama-Ba, F., Douamba, A.T.J.A., *et al*. (2021) Development of Sauce Base Technology Using Co-Products from Kilishi Production. *International Journal of Biological and Chemical Sciences*, **15**, 1544-1562. https://doi.org/10.4314/ijbcs.v15i4.19

[7] Christian Ndih, A., Ndjouenkeu, R. and Xavier Etoa, F. (2018) Meat Unwinding Techniques in Kilishi Processing in North Cameroon: Constraints and Innovations. *American Journal of Food Science and Technology*, **6**, 204-208. https://doi.org/10.12691/ajfst-6-5-2

[8] Droesbeke, J.J., Fine, J. and Saporta, G. (1997) Plans d'expériences: Applications à l'entreprise. Editions Technip.

[9] Cornell, J.A. (1941) Experiments with Mixture Designs, Models, and the Analysis of Mixture Data. 3éme Edition, Wiley/

[10] Tinsson. W. (2010) Design of Experiments: Construction and Statistical Analyses, Mathematics and Applications. Springer, 51.

[11] Scheffé, H. (1958) Experiments with Mixtures. *Journal of the Royal Statistical Society Series B*: *Statistical Methodology*, **20**, 344-360. https://doi.org/10.1111/j.2517-6161.1958.tb00299.x

[12] Piepel, G.F. (2008) Mixing Experiment. In: Ruggeri, F., Kenett, R.S. and Faltin, F.W., Eds., *Encyclopedia of Statistics in Quality and Reliability*, Wiley, 13 p.

[13] Gacem, M.A. (2011) Contribution à l'étude de l'activité antifongique et antimycotoxinogéne des extraits méthanoliques et aqueux des graines de Citrullus colocynthis sur la croissance de quelque moisissure d'altération de blé tendre stocké. Master's Thesis, Université Kasdi Merbah Ouargla.

[14] International Standardization Organization (2007) Method for the Determination of Ash in Cereals, Legumes and Their Milling Products Intended for Human Consumption.

[15] DuBois, M., Gilles, K.A., Hamilton, J.K., Rebers, P.A. and Smith, F. (1956) Colorimetric Method for Determination of Sugars and Related Substances. *Analytical Chemistry*, **28**, 350-356. https://doi.org/10.1021/ac60111a017

[16] Bradfort, M.M. (1976) A Rapid and Sensitive Method for the Quantitation of Microprogram Quantities of Protein Utilizing the Principle of Protein-Dye Binding Blue. *Phytochemistry*, **51**, 363-366.

[17] International Standardization Organization ISO 659 (2009) Oilseeds-Determination of Oil Content (Reference Method).

[18] Singleton, V.L. and Rossi, J.A. (1965) Colorimetry of Total Phenolics with Phosphomolybdic-Phosphotungstic Acid Reagents. *American Journal of Enology and Viticulture*, **16**, 144-158. https://doi.org/10.5344/ajev.1965.16.3.144

[19] Arvouet-Grand, A., Vennat, B., Pourrat, A. and Legret, P. (1994) Standardization of Propolis Extract and Identification of Principal Constituents. *Journal de Pharmacie de Belgique*, **49**, 462-468.

[20] Benzie, I.F.F. and Strain, J.J. (1996) The Ferric Reducing Ability of Plasma (FRAP) as a Measure of "Antioxidant Power": The FRAP Assay. *Analytical Biochemistry*, **239**, 70-76. https://doi.org/10.1006/abio.1996.0292

[21] Oyaizu, M. (1986) Studies on Products of Browning Reaction. Antioxidative Activities of Products of Browning Reaction Prepared from Glucosamine. *The Japanese Journal of Nutrition and Dietetics*, **44**, 307-315. https://doi.org/10.5264/eiyogakuzashi.44.307

[22] Brand-Williams, W., Cuvelier, M.E. and Berset, C. (1995) Use of a Free Radical Method to Evaluate Antioxidant Activity. *LWT—Food Science and Technology*, **28**, 25-30. https://doi.org/10.1016/s0023-6438(95)80008-5

[23] Cochran, W.G. and Cox, G.M. (1957) Experimental Design. 2nd Edition, John Wiley and Sons, 615.

[24] Tioursi, H. and Melle, T.L. (2019) Study of the Standards and Quality of Spices Used in the Maghnia Region. Master's Thesis, Université de Tlemcen, 79 p.

[25] Zaki, N., Hasib, A., Dehbi, F., El Batal, H., Hakmaoui, A., Meftah, H., Hanine, H., Latrache, H. and Ouatmane, A. (2018) Caractéristiques physicochimiques, nutritionnelles et antioxydantes du paprika produit par procédé semi-industriel à partir de la Niora (*Capsicum annuum* L.) cultivée dans trois régions Marocaines. *Revue Nature et Technologie*, **10**, 1-12.

[26] Compaore, C.S., Compaore, H., Inoussa, G.O. and Sawadogo-Lingan, H. (2020) Impact du prétraitement au sel (NaCl) et du séchage sur les caractéristiques nutritionnelles et microbiologiques de l'oignon bulbe. *International Journal of Biological and Chemical Sciences*, **14**, 685-697. https://doi.org/10.4314/ijbcs.v14i3.4

[27] Tchiégang, C. and Mbougueng, P.D. (2005) Chemical Composition of the Spices Used in the Preparation of No Poh and Nkui from West Cameroon. *Tropicultura*, **23**, 193-200.

[28] Amani, N.G.G., Tetchi, F.A. and Coulibaly, A. (2004) Propriétés physico-chimiques de l'amidon de gingembre. *Tropicultura*, **22**, 77-83.

[29] Benderradji, R. and Ghedbane, C. (2019) Phytochemical Study and Evaluation of the Biological Activities of Seven Spices Consumed in Algeria. 45.

[30] Il-Suk, K., Mi-Ra, Y., Ok-Hwan, L. and Suk-Nam, K. (2011) Department of Animal Resources Technology, Gyeongnam National University of Science and Technology, Gyeongnam. 660-758.

[31] Maizura, M., Aminah, A. and Wan, A.W.M. (2011) Total Phenolic Content and Antioxidant Activity of Kesum (*Polygonum minus*), Ginger (*Zingiber officinale*) and Turmeric (*Curcuma longa*) Extract. *International Food Research Journal*, **18**, 529-534.

[32] Kim, D., Ku, S. and Bae, J. (2012) Anticoagulant Activities of Curcumin and Its Derivative. *BMB Reports*, **45**, 221-226. https://doi.org/10.5483/bmbrep.2012.45.4.221

[33] Annou, G. (2018) Biological Activities of the Spices Constituting a "Ras el Hanout"

Mixture Used by the Inhabitants of Ouargla. 65.

[34] Atti, I. (2014) Evaluation of the Antioxidant and Anti-Free Radical Activities of a Spice Blend "Ras El Hanout". Master's Degree, Université Kasdi Merbah Ouargla, 66 p.

[35] Tacouri, D.D., Ramful-Baboolall, D. and Puchooa, D. (2013) In Vitro Bioactivity and Phytochemical Screening of Selected Spices Used in Mauritian Foods. *Asian Pacific Journal of Tropical Disease*, **3**, 253-261. https://doi.org/10.1016/s2222-1808(13)60066-3

[36] Ghedadba, N., Hambaba, L., Ayachi, A., Aberkane, M.C., Bousselsela, H. and Oueld-Mokhtar, S.M. (2015) Total Polyphenols, Antioxidant and Antimicrobial Activities of Extracts from the Leaves of Noah's Marrubium Deserti. *Phytothérapie*, **13**, 118-129. https://doi.org/10.1007/s10298-015-0944-4

[37] Bougandoura, N. and Bendimerad, N. (2012) Evaluation of the Antioxidant Activity of Aqueous and Methanolic Extracts of Saturated Jacalamintha ssp. *Nepeta* (L.) Briq. *Nature and Technology*, **9**, 14-19.

[38] Masada, K., Hosni, K., Ben Taarit, M., Hammami, M. and Marzouk, B. (2012) Effects of Crop Season and Maturity Stages on the Yield and Composition of Essential Oil of Coriander (*Coriandrum sativum* L.) Fruit. *Medicinal and Aromatic Plant Science and Biotechnology*, **6**, 115-122.

[39] Wojdylo, A., Oszmianski, J. and Czemerys, R. (2007) Antioxidant Activity and Phenolic Compounds in 32 Selected Herbs. *Food Chemistry*, **105**, 940-949. https://doi.org/10.1016/j.foodchem.2007.04.038

[40] Amir, M., Khan, A., Mujeeb, M., Ahmad, A., Usmani, S. and Akhtar, M. (2011) Phytochemical Analysis and *in Vitro* Antioxidant Activity of Zingiber Officinale. *Free Radicals and Antioxidants*, **1**, 75-81. https://doi.org/10.5530/ax.2011.4.12

[41] Falleh, H., Ksouri, R., Chaieb, K., Karray-Bouraoui, N., Trabelsi, N., Boulaaba, M., *et al*. (2008) Phenolic Composition of *Cynara cardunculus* L. Organs, and Their Biological Activities. *Comptes Rendus. Biologies*, **331**, 372-379. https://doi.org/10.1016/j.crvi.2008.02.008