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Optimizing the Fortification of Flour of Palmyra New Shoots Tubers with Powders Deriving from Cowpea Beans and Moringa Leaflets for Porridge Making

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Authors' contributions

This work was carried out in collaboration between all authors. Author BGHM supervised the whole investigation. Author MMR designed the study, performed the experiment and wrote the manuscript assisted with authors KNY and CA. Authors KNY, KNE and MMR performed the statistical analysis of the results and checked the revised manuscript. Authors SD and DMV participated in interpretation of the results. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to apply central composite design for the fortification of the meal deriving from new shoots tubers of Palmyra (*Borassus aethiopum* M.) with powders of Cowpea (*Vigna unguiculata* W.) beans and Moringa (*Moringa oleifera* L.) leaflets for gathering simultaneous maximization of the intensity of agreability, index of bitterness (low bitterness) and fluidity of the porridge resulting from the composite flour. Thus, the samples were collected between August and December 2015 from three localities, especially in the areas of Dimbokro, Toumodi and Didiévi, in the center of

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Côte d'Ivoire. Once acquired, the samples were sorted, washed, dried and processed into flour. Then, a central composite design was applied to determine the adequate proportions of each component of the composite flour in order to derive in a higher sensorial quality porridge. The independent variables selected for the study design were quantities of Palmyra flour (X1), Cowpea beans powder (X2) and Moringa leaflets powder (X3). The results highlighted needs of 50% of Palmyra, 30% of Cowpea and 20% of Moringa in the deriving composite flour for succeeding in acceptable porridge fitting with overall sensorial parameters. Accounting these conditions, the resulted porridge recorded an agreability intensity of 6.93±0.3/9, a bitterness index of 0.57±0.04/1 and a fluidity level of 6.67±0.2/9. The characteristics of this porridge are close to those predicted by the central composite design with values of 7.12, 0.55 and 6.82 for respective agreability intensity, bitterness index and fluidity.

Keywords: Central composite design; fortification; legumes; palmyra new shoots tubers.

1. INTRODUCTION

The Palmyra (*Borassus aethiopum* Mart) is a high palm tree which can reach 20 to 30 m height, belonging to the plant family of Arecaceae. It is met in the semi-arid and sub-wet zones of tropical Africa, Southern Asia, Pacific Islands, and Indian Ocean [1,2]. In Africa, the Palmyra naturally grows from Senegal to the Republic of Central Africa [3,4]. The Palmyra is located in several regions of Côte d'Ivoire, especially from the Center to the North where it represents a sentinel against the surrounding of desert. This plant is used in food [5,6,7], in traditional herbal medicine [8,9] and in technology [10]. It is also recommended for the reforestation to slow down the projection of desertification [11]. Thus, in Côte d'Ivoire, several farmers utilize the Palmyra at the adult stage for production of palm wine, a fermented drink resulting from its sap [12]. However, this production usually derives in destruction of the plant's phloem or heart. Nevertheless, palm wine production is practicable from other organs such as the unopened inflorescences of the palm trees [13]; with advantage in maintaining the plant's life. Unfortunately, the destruction of the plant heart during the palm sap production results in its earlier and systematic death [14]. This situation results in consequences on populations, especially in social, economic and nutritive impacts, and ecological concerns [15].

Besides, many populations use the new shoots of Palmyra, resulting from the germinating seeds, for food purposes. Facing all the ecological risks incurred, this way of valorization seems to be a real alternative in the plant's uses, and could ensure its survival and popularization, with significant value - added at nutritive, economic and therapeutical levels. Indeed, Palmyra trees provide numerous fruits each year, the most part of which are unutilized and go rotten before germinating [16,17]. Several research tasks have been performed concerning these fruits. Thus, from the fruit pulp, Ezoua et al. [12] produced a juice richer in soluble sugars, especially sucrose, glucose and fructose. Diby et al. [18] also obtained fruit pulp nectar which could possibly undergo alcoholic fermentation. Other researches accounted pectin resulting from the Palmyra fruits. Each fruit encloses two or three seeds generating potentially new growths after germination. The Young Palmyra shoots are tuberous and edible foods highly valued by the local populations as energetic food resource [19]. They are often processed into flour for the preparation of porridge or local fufu [7]. The flour of Palmyra is richer in starch and can undergo alcoholic fermentation after hydrolysis with the gastric juice deriving from *Archachatina ventricosa* as mentioned by Niamké et al. [14]. Other attempts revealed the preventive effect provided by the consumption of young shoots of Palmyra against the gastro duodenal ulcers and the sickly fever [20,21]. Yet, as the most of starchy foods, the young shoot tubers of Palmyra would be with lower proteins, mineral elements and vitamins contents. In this case, meals prepared on those tubers basis should be improved with other local edible vegetable sources, particularly with Cowpea (*Vigna unguiculata* Walp) and Moringa (*Moringa oleifera* Lam) which have ability in correcting the nutritional deficiency, referring to the recommendations of the *Codex Alimentarius* [22]. Beyond the improvement for the nutritive components, the porridge which will result from the composite flours will be able to display more interesting sensory characteristics, such as agreability, indexes of bitterness and fluidity, etc. From Cowpea beans, previous attempts reported high quality proteins in significant contents of about 25% [23,24]. Regarding with Moringa, the nutritional interest is related to the leaflets which are known to provide good minerals and vitamins properties [25]. Moreover, they contain the 8 or 9 human essential amino acids [26], accounting Moringa as an exceptional specie of the plant kingdom.

Considering their food interest, the development of composite recipes with Palmyra new shoots basis, fortified with Moringa leaflets and Cowpea beans, could benefit to populations. Thus, the current attempt is an investigation for optimizing the fortification of the flour deriving from new shoots of Borassus aethiopum with beans of *Vigna unguiculata* W. and leaves of *Moringa oleifera* for their fitted development. The study aims to probe the agreability, the bitterness and the fluidity of the porridge resulting from the composite flours. The influence of various flours quantities from Palmyra, Cowpea and Moringa upon the performances of the processing is evaluated. The methodology of experimental designs for surfaces responses with central composite design, for optimizing conditions such as proportions of different powders to be considered, was applied during the fortification process. It has also goal in simultaneous maximization of the intensity of agreability, the index of bitterness and the fluidity deriving from the resulted porridge.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material consisted in the flour resulting from processing of new shoots tubers of *Borassus aethiopum* Mart, and powders of *Moringa oleifera* Lam leaflets and *Vigna unguiculata* Walp beans.

2.2 Sampling

The samples were collected between August and December 2015 from three localities, especially Toumodi, Dimbokro and Didiévi, in the Centre Region which remains the natural ecological zone accommodating with Palmyra in Côte d'Ivoire and where large quantities of Cowpea and Moringa are also produced. Three (3) retailers of Palmyra shoots tubers and Cowpea beans were considered in each town. Thus, 30 kg of tubers and 10 kg of beans were perceived from each retailer, giving total of 270 kg of Palmyra tubers and 90 kg of Cowpea beans. In addition, 50 kg of fresh leaflets of Moringa were collected from two (2) sites in each town, 25 kg/site, leading to 150 kg (50 kg x 3) of leaflets. Once acquired, the samples have been conveyed to the laboratory for analyses. At the laboratory, a pool was constituted by mixing the samples deriving with each plant species. Then, 250 kg, 75 kg and 75 kg of respective samples of Palmyra tubers, Cowpea beans and Moringa leaflets were deducted, sorted, washed with distilled water and processed according to previous reports of Mahan et al. [24].

2.3 Processing for Resulting in Palmyra Flour and Powders of Cowpea and Moringa

The flour and powders of Palmyra shoots tubers, Cowpea beans and Moringa leaflets were produced as reported by Mahan et al. [24].

The new shoots tubers were washed, boiled, peeled, and carved into approximate 5 mm thickness pieces. These pieces were then rinsed and set out into 2 batches. One batch have undergone fermentation into a tank container for 24 h [27], and fermented tubers pieces were dried at 65℃ into a ventilated oven (Minergy Atie Process, France) for 6 h. The unfermented second batch of tubers pieces was also dried under the same conditions. After drying, the pieces of Palmyra tubers were ground using a hammer mill (Forplex).

The Moringa leaflets were disinfected for 5 min with chlorinated water (50 mL of 8% sodium hypochlorite in 30 L of water), rinsed and fermented for 24 h into a tank. Then, leaflets were dried at 30℃ for 10-14 days with shade ambient temperature and powdered.

Regarding with Cowpea, beans were washed, soaked, drained, and taken to sprouting at 30℃ during 48 h. The seeds were dried at 40℃ in an oven (Minergy Atie Process, France) for 96 h, and the resulted malt was sprout out, heated for 15 min in boiling water and submitted to fermentation for 24 h into a tank. The fermented Cowpea beans were then strained, roasted, dried at 50℃ in the oven for 24 h, and ground.

Finally, flour and powders were filtered using sieves with 250 µm diameter and the resulting products were put into polyethylene hermetic bags and kept into a dry place till analyses.

2.4 Central Composite Experimental Design

The central composite design was used to obtain the quite proportions of components in the resulted flour for having a good quality porridge (good intensity agreability, good index of bitterness and good fluidity). The design independent variables selected for this study were the quantity of Palmyra flour (X1), the quantity of Cowpea powder (X2), and the quantity of Moringa powder (X3) (Table 1).

For this design, each factor presented 5 levels (-α, -1, 0, +1 and + α). Referring to works of Feinberg [28], the combination of three factors levels results in 20 experimental runs (20 formulations) comprising eight factorial points, six axial points (two axial points on each design variable axis at a distance of 1.68 from the design center) and six replicates at the center point (Table 2). Three experimental responses were studied, namely intensity of agreability (Y1), bitterness index (1/Y2), and fluidity index (Y3).

2.5 Sensory Analysis

For each fortification essay, the porridge prepared from the composite flour obtained was subjected to descriptive analysis for assessing and quantifying the intensity of agreability (Y1), the index of bitterness (1/Y2) and fluidity (Y3).

2.5.1 Selection and training of panelists

Twenty volunteers were recruited for their ability in appreciation of the aromas, flavours, and textures. These persons have been trained concerning the methodology of analysis and appreciation of the qualitative characters selected according to requirements of sensory analysis [29]. Panelists have been taught on the taste areas of the tongue. Then, they were accustomed with the porridge resulting from standard infantile flours for eight training sessions of tasting [30].

Table 1. Independent variables and their coded and real values used for optimization

Independent variables	Symbol	Coded levels				
		-1,682	**-1**	**0**	**+1**	**+1,682**
Quantity of Palmyra flour (g)	X_1	50	57	67,5	78	85
Quantity of Cowpea powder (g)	X_2	10	14	20	26	30
Quantity of Moringa powder (g)	X_3	5	8	12,5	17	20

Table 2. Experimentation table of the central composite design

Group tests	N° Test	Coded and actual values of the factors		
		X1(%)	**X2(%)**	**X3(%)**
Factorial tests	1	-1 (72)	-1 (18)	-1 (10)
	2	1 (78)	-1 (14)	-1 (8)
	3	-1 (62,5)	1 (28,5)	-1 (9)
	4	1 (70)	1 (23)	-1 (7)
	5	-1 (65)	-1 (16)	1 (19)
	6	1 (71,6)	-1 (12,8)	1 (15,6)
	7	-1 (57)	1 (26)	1 (17)
	8	1 (64,5)	1 (21,5)	1 (14)
Axial tests	9	-1,682 (61)	0 (24)	0 (15)
	10	1,682 (72)	0 (17)	0 (11)
	11	0 (75)	-1,682 (11)	0 (14)
	12	0 (61,4)	1,682 (27,3)	0 (11,3)
	13	0 (73)	0 (21,6)	-1,682 (5,4)
	14	0 (62,8)	0 (18,6)	1,682 (18,6)
Center tests	15	0 (67,5)	0 (20)	0 (12,5)
	16	0 (67,5)	0 (20)	0 (12,5)
	17	0 (67,5)	0 (20)	0 (12,5)
	18	0 (67,5)	0 (20)	0 (12,5)
	19	0 (67,5)	0 (20)	0 (12,5)
	20	0 (67,5)	0 (20)	0 (12,5)

X1, quantity of Palmyra shoots flour (%); X2, quantity of Cowpea powder (%); X3 quantity of Moringa leaflets powder (%)

2.5.2 Preparation of porridge

Four porridges were cooked per tasting session, by introducing 50 g of flour into 250 mL of distilled water. Cooking lasted 5 min on a soft fire. The porridge of composite flours was prepared under the same conditions without any ingredients for better characterization of each porridge. Porridge were cooled at room ambient temperature before serving.

2.5.3 Presentation of porridge for analysis and evaluation method

Porridge samples for analysis were presented to a jury of 15 trained panelists. These samples were served with bowls of similar aspect, three-digits coded, and monadiquely presented to each panelist in a random order. The pleasure perceived by each panelist was scored on a 9 points rating scale where 1 expressed the lack of sensation and 9 expressed the full sensation.

2.6 Sensory Analysis

Multiple linear regression analysis was performed using Statistica 8 software (Stat Soft, Inc., USA). Experimental data were fitted to the following second-order polynomial pattern, and regression coefficients were obtained.

$$Y_n = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

With: Yn, Experimental response; bn, values of corresponding regression coefficients; X1, X2, and X3, respective quantities of Palmyra tubers flour, and powders of Cowpea beans and Moringa leaflets.

3. RESULTS AND DISCUSSION

3.1 Experimental Responses Resulted from the Central Composite Design

Overall responses after the 20 essays of the experimental matrix, are recorded in Table 3.

The intensity of agreability of prepared porridge varies between 3.88 and 6.78. The lowest intensity of agreability is obtained from the meal combining 78% of Palmyra, 14% of Cowpea and 8% of Moringa. On the other hand, the highest intensity of agreability results from mixture of 57% of Palmyra, 26% of Cowpea and 17% of Moringa.

The indexes of bitterness and fluidity of prepared porridges vary from 0.30 to 0.54 and 3.07 to 6.27, respectively. The greatest bitterness index (0.54) and fluidity index (6.27) were

Table 3. Responses surfaces of central composite design and experimental results

Test set	Independent variables			Experimental responses		
	X_1 (%)	X_2 (%)	X_3 (%)	Y_1	$1/Y_2$	Y_3
1	-1 (72)	-1 (18)	-1 (10)	5.56	0.45	4.28
2	1 (78)	-1 (14)	-1 (8)	3.88	0.30	3.07
3	-1 (62.5)	1 (28.5)	-1 (9)	6.00	0.48	4.54
4	1 (70)	1 (23)	-1 (7)	4.90	0.38	3.13
5	-1 (65)	-1 (16)	1 (19)	5.78	0.47	6.08
6	1 (71.6)	-1 (12.8)	1 (15.6)	4.15	0.37	4.47
7	-1 (57)	1 (26)	1 (17)	6.78	0.54	6.27
8	1 (64.5)	1 (21.5)	1 (14)	5.76	0.43	4.4
9	-1.682 (61)	0 (24)	0 (15)	6.50	0.53	5.56
10	1.682 (72)	0 (17)	0 (11)	4.05	0.31	3.13
11	0 (75)	-1.682 (11)	0 (14)	4.80	0.34	4.27
12	0 (61.4)	1.682 (27.3)	0 (11.3)	5.67	0.47	4.53
13	0 (73)	0 (21.6)	-1.682 (5.4)	5.12	0.36	3.16
14	0 (62.8)	0 (18.6)	1.682 (18.6)	5.69	0.45	6.20
15	0 (67.5)	0 (20)	0 (12.5)	5.48	0.43	4.57
16	0 (67.5)	0 (20)	0 (12.5)	5.49	0.43	4.64
17	0 (67.5)	0 (20)	0 (12.5)	5.41	0.42	4.47
18	0 (67.5)	0 (20)	0 (12.5)	5.38	0.43	4.62
19	0 (67.5)	0 (20)	0 (12.5)	5.30	0.42	4.55
20	0 (67.5)	0 (20)	0 (12.5)	5.23	0.41	4.58

Y1, Agreability (rating/9); 1/Y2, index of bitterness (reverse of the rating/9 of bitterness); Y3, index of fluidity (rating/9) obtained with the same combination so as the agreability (57% Palmyra, 26% Cowpea and 17% Moringa). Also, the porridge formulation of 78% Palmyra, 14% Cowpea and 8% Moringa leads to the lowest bitterness and fluidity indexes with respective values of 0.30 and 3.07 (Table 3). From central composite design, the relationships between the various descriptors and the resulted responses therefrom are in the forms:

$$Y_3 = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

$$\frac{1}{Y_2} = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

$$Y_3 = b_o + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$$

The different coefficients and their significance were determined using the experimental matrix and the results of various measurements. Statistical analysis of the results of Table 3 was used for determining the coefficients assigned to each parameter for each response, the coefficient of determination (R^2) between the experimental and predicted values for each response and the failure in fitting (Table 4). The values of coefficient of determination (R^2) for the regression pattern of agreability, and bitterness and fluidity indexes were 0.97, 0.97 and 0.99, respectively. Non-significant fitting default is got for each response.

For better estimation of the effect of the various operating conditions upon the responses, spatial 3D representation was performed (responses surfaces representation) by fixing one of the parameters at its level zero (center of the experimental design) for examining responses surfaces according to the other selected parameters.

3.2 Effect of Process Variables on Porridge Agreability

The intensities of agreability for porridge expressed by panelists on central composite design basis are shown in Table 3. Multiple regression analysis was performed on the experimental data and the coefficients of the model are evaluated for significance. Quantities of Palmyra, Cowpea and Moringa effects are highly significant (P=.001). The individual effects and interactions of the factors were determined (Table 4). For reminding, a coefficient preceded by a sign (+) is with a positive influence on the response, while the negative sign (-) reflects negative influences on the response. Only significant coefficients are used to describe the following mathematical pattern:

$$Y_1 = 5.38 - 1.4\,X_1 + 0.81\,X_2 + 0.45\,X_3 + 0.30\,X_1X_2 + 0.29\,X_2X_3$$

Table 4. Regression coefficients of predicted quadratic polynomial patterns for indexes of agreability, bitterness and fluidity of the porridge

Coefficients	Coefficient estimated		
	Agreability	**Index of bitterness**	**Fluidity**
b_0	5.38^{***}	0.42^{***}	4.57^{***}
Linear			
b_1	-1.4^{***}	-0.12^{***}	-1.49^{***}
b_2	0.81^{***}	0.07^{***}	0.13^{**}
b_3	0.45^{***}	0.05^{***}	0.66^{***}
Quadratic			
b_{11}	-0.05^{ns}	0.00^{ns}	-0.13^{**}
b_{22}	-0.8^{ns}	0.00^{ns}	-0.10^{ns}
b_{33}	0.04^{ns}	0.00^{ns}	0.10^{ns}
Cross products			
b_{12}	0.30^{**}	0.01^{ns}	-0.12^{ns}
b_{13}	0.03^{ns}	0.01^{ns}	-0.21^{**}
b_{23}	0.29^{**}	0.00^{ns}	-0.05^{ns}
R^2	0.97	0.97	0.99
Fitting default (P-value)	0.05^{ns}	0.07^{ns}	0.07^{ns}

* Significant at p=.05; ** significant at p=.01; *** significant at p=.001; ns: no significant; R^2: regression coefficient; p: probability

All linear terms (X1, X2, and X3), interactions between Palmyra (X1) and Cowpea (X2) and between Cowpea (X2) and Moringa (X3) are significant (p=.001).

The Palmyra quantity record a negative effect upon the porridge agreability as shown by the negative corresponding coefficient of -1.4. Oppositely, individual effects of the Cowpea and Moringa quantities are positive for sensory agreability of porridge, with respective corresponding coefficients of +0.81 and +0.45.

Accordingly to the equation mentioned below, Fig. 1A shows positive effect from the interaction between Palmyra and Cowpea upon the agreability of porridges when the Moringa quantity is considered at its zero level. Fig. 1B shows a significant effect of the quantities of Moringa and Palmyra on the agreability with constant Cowpea content of 20%, similar to description of Fig. 1A. Also, positive effect in accounted from the interaction between quantities of Cowpea and Moringa on agreability of porridge with constant Palmyra content of 67.5% (Fig. 1C).

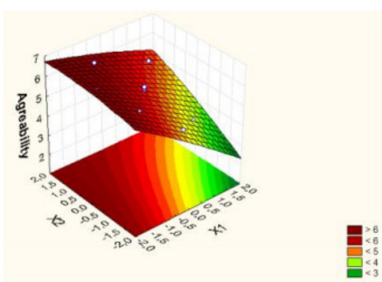
3.3 Effect of Process Variables on the Bitterness Index

The quantities of Palmyra, Cowpea and Moringa result in high significant effects upon the bitterness index (P=.001) of the porridge deriving from the composites flours (Table 3). The different coefficients assigned to each factor are shown in Table 4. The resulting mathematical pattern is:

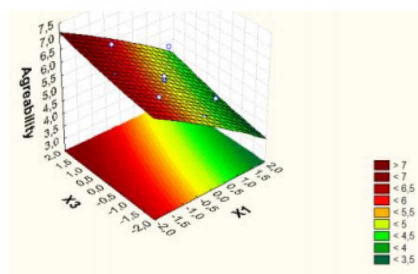
$$1/Y_2 = 0.42 - 0.12\ \mathrm{X}_1 + 0.07\ \mathrm{X}_2 + 0.05\ \mathrm{X}_3$$

The quantity of Palmyra flour has a negative effect upon the bitterness index of the porridge with coefficient of -0.12. Oppositely, the effects of Cowpea and Moringa quantities are positive, with respective coefficients of 0.07 and 0.05.

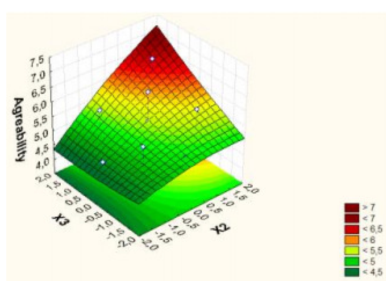
Fig. 2A and 2B show significant dropping of the bitterness index deriving with both increasing of Palmyra quantity and constant Moringa or Cowpea quantities at zero level. On the contrary, the bitterness index is strengthened with increasing of Cowpea or Moringa quantities. Also, from the selected experimental domain, a



(A): Effect of PALM & COWP with 12.5% MOR



(B): Effect of PALM & MOR with 20% COWP



(C): Effect of COWP & MOR with 67.5% PALM

Fig. 1. Responses surfaces of agreability of porridge

COW, Cowpea beans powder; MOR, Moringa powder; PALM, Palmyra tubers flour constant Palmyra quantity of 67.5% associated to the increasing of Cowpea and Moringa quantities result in quite increase of bitterness index (Fig. 2C).

3.4 Effect of Process Variables on the Fluidity

The fluidity index mentioned by panelists from the porridge on the central composite design basis is also shown in Table 3. Quantities of Palmyra, Cowpea and Moringa have high significant effects (P=.001). The individual, quadratic effects, and interactions of the different factors were determined (Table 4). The associated mathematical pattern is got as below:

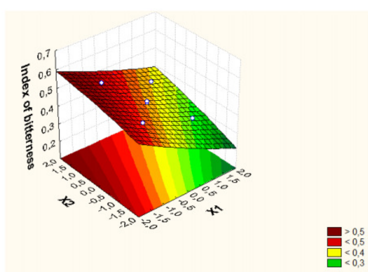
$$Y_3 = 4.57 - 1.49\,X_1 + 0.13\,X_2 + 0.66\,X_3 - 0.13\,X_1^2 - 0.21\,X_1X_3$$

Overall main terms are with significant influence (p=.001). The quantity of Palmyra has negative effect upon the fluidity, with negative coefficient value of -1.49. Reversely, the individual effects of Cowpea and Moringa quantities are positive (0.13 and 0.66) for the fluidity of the porridge. Besides, quadratic effects of Palmyra quantity are noted (-0.13). There are also significant interactions between quantities of Palmyra and Moringa upon the porridge fluidity (-0.21).

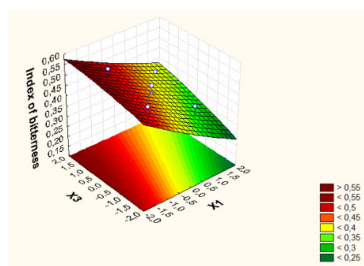
Fig. 3 illustrates the equation mentioned above. It shows the relationship between all the technological factors from the experimental domain, when fixing one of them at its zero level. Fig. 3A presents the effect of Palmyra and Cowpea upon the fluidity with constant Moringa quantity at zero level. The increasing of Cowpea quantity results in rising of the porridge fluidity when the increasing of the Palmyra quantity involves decrease of this fluidity. A slight curvature due to the negative quadratic effect of Palmyra (X_1^2) on fluidity is observed from Fig. 3A. Fig. 3B shows negative effect of the interaction between quantities of Palmyra and Moringa upon the fluidity if Cowpea is at zero level of 20%. Fig. 3C indicates that for a constant Palmyra quantity of 67.5%, the increasing of the Cowpea quantity doesn't affect considerably the fluidity of the porridge. On the other hand, increasing of Moringa results in rising of the fluidity index.

3.5 Optimization and Experimental Validation

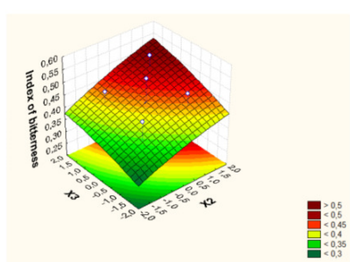
Optimal improvement conditions for the quality of porridge are with 50% of Palmyra, 30% of Cowpea and 20% of Moringa, as predicted using desirability function of Statistica 8.0 software,



(A): Effect of PALM & COW with 12.5% MOR

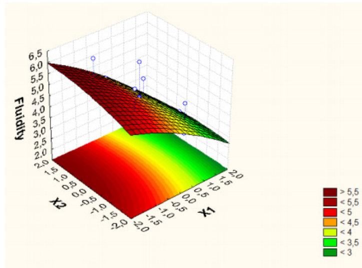


(B): Effect of PALM & MOR with 20% COW

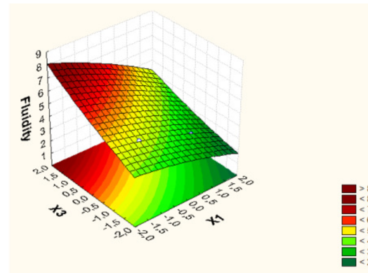


(C): Effect of COW & MOR with 67.5% PALM

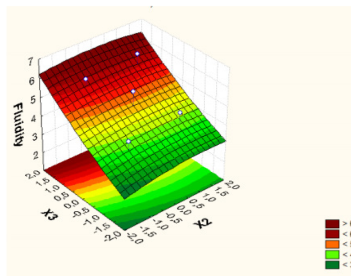
Fig. 2. Responses surfaces of bitterness index of porridge
COW, Cowpea beans powder; MOR, Moringa powder; PALM, Palmyra tubers flour



(A): Effect of PALM & COW with 12.5% MOR



(B): Effect of PALM & MOR with 20% COW



(C): Effect of COW & MOR with 67.5% PALM

Fig. 3. Responses surfaces of fluidity of porridge

COW, Cowpea beans powder; MOR, Moringa powder; PALM, Palmyra tubers flour

from simultaneous maximization of agreability intensity, and indexes of bitterness and fluidity. The prepared porridge deriving from this composite flour has an agreability intensity of 6.93±0.3, a bitterness index of 0.57±0.04 and a fluidity index of 6.67±0.2 (Table 5). The statistical analysis showed any obvious difference between the results of the various evaluations and the predictions from the regression pattern ($p \geq .001$).

Table 5. Predicted and experimental values of responses under optimal condition

Responses	Observed value	Predicted value
Agreability	6,93±0,3^{a}	7,12^{a}
Index of bitterness	0,57±0,04^{c}	0,55^{c}
Fluidity	6,67±0,2^{b}	6,82^{b}

From the same line, values with different lowercase letters are significantly different at p=.05

3.6 Discussion

The coefficients of determination (R^2) from regression patterns were close to 1. Such results forecast the validity of the predictions resulting from the 2nd order polynomial pattern for the real responding [31]. The non-significance of the fitting default resulting with each response indicates the quite adjustment of the patterns [32]. So, the results obtained from the central composite design are valuable in the selected experimental domain.

The different flours quantities from Palmyra, Cowpea and Moringa in the composite meal have a significant effect upon the intensities of agreability, bitterness and fluidity. This involves in predominant role of the three variables in this fortification process.

The negative individual effect of the quantity of Palmyra flour is so obvious that the increasing in the quantity of this raw food within the composite flour results in decrease of the agreability intensity, and the indexes of bitterness and fluidity. The Palmyra flour is with negative influence in the agreability, and bitterness and fluidity indexes deriving from the composite porridge. This could be caused by the bitter taste of the new shoots tubers of Palmyra. The negative effect of the Palmyra flour upon the fluidity could be explained by the great starch content (35.24%) of the Palmyra tubers [19,5].

The results highlighted increases of the agreability intensity, and the bitterness and fluidity indexes of the porridge, with quantities of Cowpea and Moringa from the selected experimental domain. The positive effect of Moringa upon the fluidity in this process would be due to its lower carbohydrates content [24]. Moreover, the powder of Moringa leaflets provides appreciable taste.

The positive effect accounted from the content of Cowpea powder for agreability, bitterness and fluidity of the porridge would be due to germination, fermentation and the roasting undergone by Cowpea beans for the production of the Cowpea powder. Indeed, germination results in increase of the fluidity of the porridge deriving from sprouted grains meal [33]. Elenga et al. [34] also showed that germination and fermentation of the maize grains reach in more fluidity of their porridge. Also, fluidity and agreability of porridge are favored by roasting which reduces the water content and modifies the structure of starch and proteins [35,36].

The results of optimization and the experimental validation indicate the existence of a good similarity between effective responses and predicted values. In these conditions, according to Koffi et al. [37], the central composite design is successfully performed for optimizing the fortification of the flour deriving from new shoots tubers of Palmyra with the powders of Cowpea beans and Moringa leaflets.

4. CONCLUSION

In this study, a central composite design was applied for optimizing the fortification of composite flour on Palmyra new shoots tubers basis with powders of Moringa leaflets and Cowpea beans. The agreability intensity, and the bitterness and fluidity indexes of the resulting porridge were accounted. Optimal fortified composite flour should contain 50% of Palmyra, 30% Cowpea and 20% Moringa. The porridge prepared in these conditions has agreability intensity of 6.93±0.30/9, and respective bitterness and fluidity indexes of 0.57±0.04/1 and 6.67±0.20/9. These characteristics are similar to the statistical predictions got from desirability function of Statistica 8.0. Therefore, fortification of the flour provided by the new shoots tubers of *Borassus aethiopum* was optimized successfully using central composite design in simultaneous results of good intensity of agreability, and acceptable index of bitterness and good fluidity for porridge of the composite flour. This flour could be used to fight against nutrition hazards, specifically for the children in rural conditions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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