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LOCAL RESOURCE EXPLOITATION

Influence of pretreatments of some local foods on the composition and viscosity of infant gruels

Influence des prétraitements de quelques denrées locales sur la composition et la viscosité des bouillies infantiles

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ABSTRACT:

The influence of pretreatments of cocoa beans (*Theobroma cacao*), soybeans (*Glycine max*) and maize (*Zea mays*) on the chemical composition and viscosity of infant gruel was investigated. The compositions of raw and pretreated flours obtained from cocoa beans, soybeans and maize were determined using normalized analytical methods. The best flours obtained, according to their compositions (high soluble sugar content and energy density), were used for the experimental design. Mixture design methodology was applied having as factors the flours constituents and the responses were the energy value and the viscosity. An optimization was done according to the specifications so as to determine the best gruel formulation with high energy value and low viscosity, for infant feeding. This study reveals that steeping induces an increase in soluble sugars of maize and soybeans while roasting leads to an increase in the lipid content of soybeans and cocoa beans. Results from the optimization procedure show that the optimal point (0.62 for steeped maize, 0.13 for steeped soybeans and 0.25 for roasted cocoa beans) leads to a flour mixture with sufficient energy requirement (545.16 kcal), having the best rheological properties required for infant gruels.

Keywords: *Theobroma cacao*, *Glycine max*, *Zea mays*, Pretreatments, Mixture design, Infant gruels.

RÉSUMÉ :

L'influence des prétraitements des fèves de cacao (*Theobroma cacao*), du soja (*Glycine max*) et du maïs (*Zea mays*) sur la composition et la viscosité des bouillies infantiles a été étudiée. Les compositions des farines non prétraité et prétraitées obtenues à partir des fèves de cacao, de soja et de maïs ont été déterminées en utilisant des méthodes analytiques normalisées. Les meilleures farines obtenues, en fonction de leurs compositions (haute teneur en sucres solubles et densité énergétique), ont été utilisées pour le plan d'expérience. La méthodologie du plan de mélange a été appliquée en prenant comme facteurs les constituants de la farine et les réponses étaient la valeur énergétique et la viscosité. Une optimisation a été faite selon le cahier des charges afin de déterminer la meilleure formulation de bouillie ayant une haute valeur énergétique et à faible viscosité, pour l'alimentation des nourrissons. Cette étude révèle que le trempage induit une augmentation des sucres solubles du maïs et du soja tandis que la torréfaction conduit à une augmentation de la teneur en lipides du soja et des fèves de cacao. Les résultats de la procédure d'optimisation montrent que le point optimal (0,62 pour le maïs trempé, 0,13 pour le soja trempé et 0,25 pour les fèves de cacao torréfiées) conduit à un mélange de farine avec un besoin énergétique suffisant (545,16 kcal), ayant les meilleures propriétés rhéologiques requises pour les bouillies infantiles.

Mots clés : *Theobroma cacao*, *Glycine max*, *Zea mays*, Prétraitements, Plan de mélange, Bouillies infantiles.

1. INTRODUCTION

In developing world, infant malnutrition is a serious and widespread problem which has lifted efforts in research, development and extension by both local and international organizations. As a result, in Cameroon and many others developing countries, the formulation and development of nutritious weaning foods from local and readily available raw materials have received a lot of attention. Malnutrition is a major health problem in developing countries and contributes to infant mortality, poor physical and intellectual development of infants, as well as lowered resistance to disease and consequently stifles development (FAO Statistics Division, 2009; Kadam, 2012). Nationally, 32 % of children under 5 suffer from stunting and the rate is over 50 % in the northern and eastern part of the country, where the problem is most acute (UNICEF, 2020). Protein-energy malnutrition generally occurs during the crucial transitional phase when children are weaned from liquid to semi-solid or fully adult foods.

Gruel is generally used as weaning food for baby or young children and as a standard breakfast cereal for many homes (Faber et al., 2001). As cereals are commonly low in protein, fortification of cereals with locally available legume that is rich in protein increases protein content of cereal-legume blends. Many authors worked on the complementary selection of food products for the improvement of gruel such as sorghum/sesame (Maka and Jiokap, 2017), sorghum/soybeans (Adelekan and Oyewole, 2010), maize/soybeans (Akanbi et al.,2003; Apotiola, 2013) and so on. Soybeans has a carbohydrate content of about 18 % but has a high protein content of about 44 % (Salunkhe and Kadam, 1989) making the crop a suitable complement for maize. Similarly, cocoa is a source of protein, minerals and antioxidants (Lee et al., 2003), widely used for the production of beverage and confectioneries. Odunlade et al. (2016) concluded that inclusion of cocoa powder enhanced the functional and antioxidative properties of the enriched sorghum blend. High malnutrition indices and the need to increase gross domestic products through alternative valorization therefore required an evaluation of the possible use of cocoa in gruel. There is a paucity information on infant gruel made from maize, enriched by soybeans and cocoa beans. This will not only reduce nutritional deficiencies in the population but equally contribute in enhancing food security. An increased in Cameroon's annual production of these three crops has been recorded and about 308,753 tons of cocoa, 24,558 tons of soybeans and 2,164,003 tons of maize has been attained in 2017 (FAOSTAT, 2018).

The weaker and poorly coordinated nature of infant's digestive tract, necessitates a more fluidify gruel so as to ease digestion. Pretreatments operations can be used to fluidify food gruel while at the same time improve on the nutrients bioavailability Many research works have been done on the pretreatment of raw materials. Some authors have reported a reduction in viscosity with sprouting (Adegbehingbe, 2013), soaking (Bolaji et al., 2017; Agume et al., 2017, Apotiola, 2013), souring (Akanbi et al.,2003; Adeyemi et al., 1986), enzymatic treatment (Trèche and Giamarchi, 1991) and roasting (Agume et al., 2017). Other reported an increase in viscosity with defatting (Odunlade et al., 2016; Line Do et al., 2011) and drying temperature (Bolaji et al., 2014).

The consistency of the porridge obtained at the end has to be well mastered as infant guts are still weak, narrow and less active (Giamarchi and Trèche, 1995; Laurent, 1998; Mouquet et al., 1998). Hence, the major challenge of obtaining a less viscous (≤ 1 Pa.s), energy dense (≥ 400 kcal/100 g MS) complementary food readily available and suitable for infant digestive system (CODEX, 2006). The overall objective of this work is to determine the influence of pretreatment types done on maize, soybeans and cocoa beans on the chemical composition and viscosity of infant's gruels.

2. MATERIALS AND METHODS

2.1. Materials

The raw materials used for gruel production were maize (Zea mays), soybeans (Glycine max), both purchased from local markets in Ngaoundere (Adamawa Region, Cameroon) and cocoa beans (Theobroma Cacao L) were obtained from Bafia, Centre region of Cameroon.

2.2. Methods

2.2.1. Raw material pre-processing

The maize was sorted, winnowed, and washed twice with distilled water. The cleaned grains were soaked in distilled water for 72 h at ambient temperature with the soaking water renewed after 24 hours (Bolaji et al., 2013). After soaking, the seeds were then drained using a sieve, spread on a wet tissue that was made to imbibe water every 24 h, and dried in an oven for 24 hours at 50 °C. The dried seeds were milled and sieved to obtain small particle-sized flour (< 250µm).

The soybeans were sorted and divided into two portions treated as described by Agume et al., (2017). The first portion was washed twice with distilled water and soaked in distilled water for 48 h at ambient temperature with the soaking water renewed after 24 hours. After soaking, the seeds were dehulled then drained using a sieve, spread on a wet tissue that was made to imbibe water every 24 h, and dried in an oven for 48 hours at 50 °C. The dried seeds were milled and sieved to obtain small particle-sized steeped soybean flour (< 250µm). The second portion after sorting was roasted at a temperature of 100 °C for 10 minutes following by cooling. The cocoa beans were milled and sieved to obtain roasted soybeans flour (< 250µm).

Cocoa beans were processed as described by Bentivegna et al (2002). The cocoa beans were sorted and roasted at a temperature of 135 °C for 45 minutes followed by cooling. The cocoa beans were shelled and the shells were separated from the nibs. The nibs were milled and divided into two portions. The first portion was packaged while the second portion was pressed to extract the cocoa butter. The powder obtained was sieved and packaged to obtain defatted cocoa powder (< 250µm).

2.2.2. Gruel preparation

The flours were mixed for 5 min with water at 45 °C (using a flour to water ratio of 0.3:0.7 w/v) and the mixture was placed in a stainless-steel pot (2 L capacity) and cooked with gentle heat using a burner gas stove for 10 min at atmospheric pressure, after reaching 95 °C. The mixture was slowly stirred during cooking using a stainless-steel spoon. (inspired by Trèche and Mouquet (2008)), this procedure leads to the production of low viscosity purées and as such, most appropriate for infants.

2.2.3. Physicochemical analysis

The water contents were determined by the AOAC (1999) method, the ash content by AOAC (1990) method and the lipid content by bourely (1982). The crude proteins contents were determined after mineralization by the kjeldahl method (AFNOR, 1984), and determination through colorimetric method (Devani et al., 1989).and the protein content was determined using the conventional conversion coefficient of 6.25 (AOAC, 1975). Soluble sugars were extracted and determined according to the method described by Fischer and stein (1961) using the DNS (3,5 dinitro salicylic acid) colorimetric method and the total available sugars were determined in the same way after hydrolysis of the sugars by hydrogen sulfate (H_2SO_4, 1.5 N).

2.2.4. Energy value determination

The energy values were determined by the EEC (1990) conversion method, given that 1 g of carbohydrate provides 4 kcal, 1 g of lipid provides 9 kcal and 1 g of protein provides 4 kcal. the Energy values (Ev) were calculated as follows (Equation 1):

$$Ev = 4X+4Y+9Z \quad (1)$$

Where X, Y and Z are respectively the dry matter percentages of carbohydrates, proteins and lipids.

2.2.5. Viscosity determination

Viscosity measurements were carried out using the Brookfield DV-III Ultra rheometer (model HBDV-III Ultra, 8534447, Brookfield Engineering Lab., Massachusetts, USA) using a disk-shaped spindle HA/HB-2 of 133 mm height; 48 mm diameter and 1.6 mm thickness. Viscosity measurement were done at a temperature of 30 °C by monitoring the evolution of gruel viscosity (30 % gruel) with time at a constant shear rate of 100 rpm.

2.2.6. Mixture design of the gruel flours

A simplex centroid mixture design with constraints was used for the formulation of gruel which has been design with the help of Minitab XVII. The mixture design method was used to determine the optimal mixing proportions of the three different ingredients (maize flour, soybeans flour and cocoa powder) used in the production of a gruel flour mixture respecting the nutritional, rheological and energy specifications presented in table 1. The various levels (low and high) were fixed based on the specification in table.2

Table 1: Specifications of infant food gruels for babies between 4 months and 3 years.

Chemical composition (Per 30g of dry matter)	Minimum	Maximum	Units	References
Energy value	120	-	kcal	Sanogo, 1994 ; Mouquet et al., 1998 and CODEX (2006)
Soluble sugars	Maximize		G	
Carbohydrates	25	70	G	
Proteins	12	22	G	
Lipids	10	18	G	
Viscosity	-	1	Pa.s	Gerbouin-Rerolle (1996).

Table 2: Experimental component and constrained mixture

Components	Constraints		
	Lower bound (%)	Upper bound (%)	Literature
Maize flour	60	80	Cereals > 60 % (Alabi and Anonye, 2007; Adelekan and Oyewole, 2010).
Soyflour	10	30	Alabi and Anonye, 2007; Bolaji et al., 2010; Odunlade et al., 2016
Cocoa powder	10	30	

10 experimental points were obtained from an augmented simplex centroid design (Figure 1) and 3 repetitions were done at the center so as to improve on the accuracy of the results.

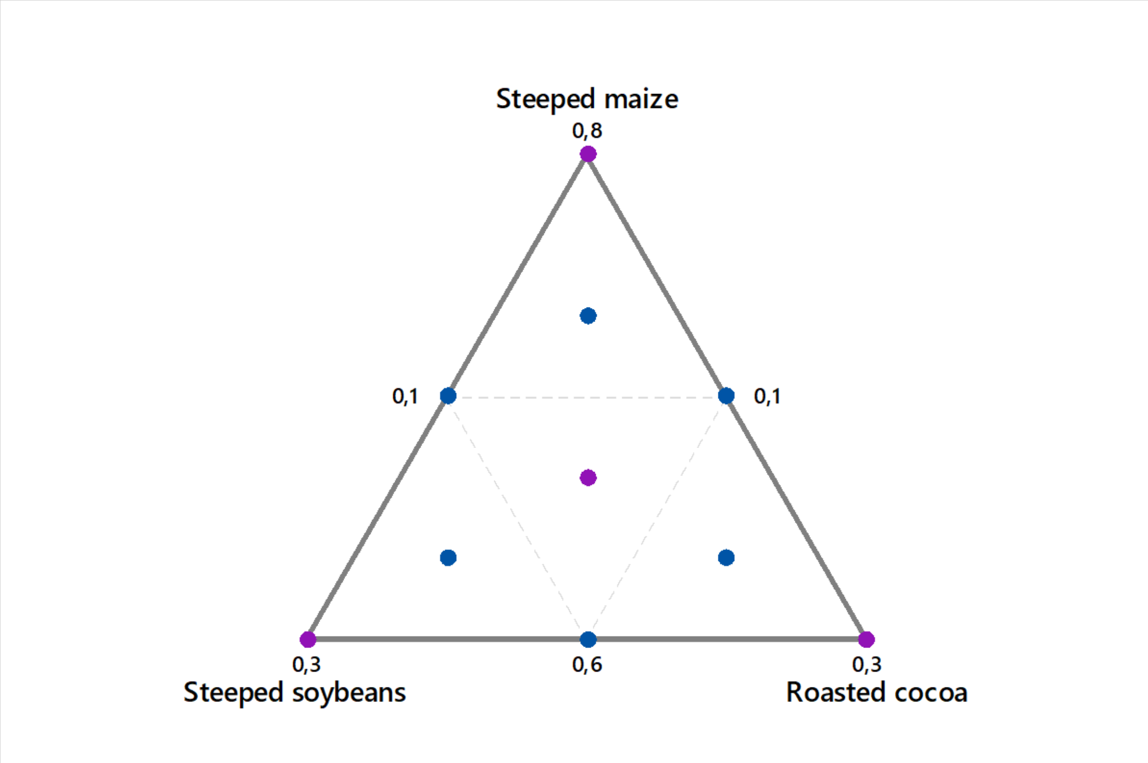

Figure 1: Actual representation of the experimental domain

2.2.7. Mixture modelling and optimization

An appropriate mixture model for modeling the response data as functions of the mixture components and other factors selected for the experiment is chosen. The design points in this design will support the polynomial model, which is the special cubic model (q = 3).

$$Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3 \quad (2)$$

Where: x_1: Maize pap flour percentage, x_2 :Soyflour percentage, x_3 : Cocoa powder percentage, $Y1$: Energy value, $Y2$: Viscosity

2.2.8. Statistical analysis and model validation

The results are presented as mean ± standard deviation and analysis of variance (ANOVA) is used to compare the means ($P < 0.05$) obtained using Excel 16 and Minitab 18. The response obtained from the mixture design is represented using a three-dimensional response surface plot generated with the help of Design expert 12. The validation of the models was done by comparing the values of the coefficient of determination (R^2), adjusted coefficient of determination (R^2_{adj}) and the bias factor (B_f).

3. RESULTS AND DISCUSSION

3.1. Chemical characteristics of the flour

Table 3 shows the chemical composition of raw and pretreated materials precisely dry matter, ash, soluble sugars, total sugars, lipids and proteins content. From these results, a noticeable significant difference ($P<0.05$) exists in the soluble sugars between raw maize and raw soybeans and between maize and raw cocoa. Pretreatment operations done on maize and soybeans do not have significant effect (P<0.05) on the total carbohydrate meanwhile the have significant effect on the total carbohydrate of cocoa. Soluble sugar content is lower than the total carbohydrate content for all the flours.

Roasting of cocoa and soybeans decrease their moisture content. Roasting the soybean led to a significant (p < 0.05) decrease of moisture content, from a mean value of 11.2 g/100 g dw to.7.11 g/100 g dw. Since the moisture content of the flour is a consequence of its hygroscopic character, it is likely to conclude that roasting decreases the ability of soybean flour to interact with water. The low level of moisture expected in pretreated flours could be as a result from the high temperature (which eliminates water more quickly), and the intermolecular cross-linking that might occur (Agume et al., 2016). The moisture content of maize and soybeans did not vary significantly with soaking. A similar effect of soaking on the moisture content of maize flour has been reported by Agume et al (2016; 2017).

Soluble sugar content is lower than the total carbohydrate content for all the flours. However, the soluble sugar content is higher in steeped flour (1.71 g/100 g dw to 5.39 g/100 g dw) than in the raw material. This is due to the increase in α-amylases activity resulting to an increase in starch hydrolysis (Elkhalifa and Bernhardt, 2010). An increase in soluble sugar is observed in defatted cocoa as a result of defatting thereby increase the soluble sugar content for a given mass of flour. Soluble sugars are very important in infant gruel as they are easily and firstly taken up by the organism. Soluble sugars contribute in fluidifying the gruel thereby facilitating their flow in the infant digestion gut. Meanwhile starch is not easily digested by newborns and contribute in the thickening the gruel.

Pretreatment of maize, soybeans and cocoa has significant effect on the protein content (P<0.05). Steeped maize and soybeans flours exhibit lower protein content than raw maize and soybeans respectively. Loss of soluble proteins during soaking through leaching probably contributes to the decrease in protein content of pretreated flour (Hama et al., 2009). A slight decrease in protein is observed in roasted soybeans and roasted cocoa (31.75 g/100 g dw to 27.68 g/100 g dw and 19.87 g/100 g dw to 19.21 g/100 g dw respectively). This is due to the maillard's reaction that took place during roasting using up small amount of sugars and proteins (Agume et al., 2016). Decrease in proteins and total sugars during soaking of maize has been reported by Hama et al. (2009).

Lipid content of steeped soybeans flour (18.67 g/100 g dw), roasted soybeans flour (21.44 g/100 g dw) and roasted cocoa (50.23 g/100 g dw) is higher than in raw soybeans and cocoa. The increase in lipid during soaking probably is as a consequence of the leaching of soluble components, causing a concentration of the lipids in the flour. Roasting results in the reduction of viscosity of the oil in the cells easy its extraction and diffusion with the solvent out of the cells similarly there is an increase in lipid in defatted cocoa due to the destruction of cell structure and the efficient release of oil reserve during pressing (Cuevas-Rodriguez et al., 2004). An increase in oil content after roasting has been reported for cereal seeds including millet (Sade et al., 2009).

The ash content decrease in soaked maize and soybeans flour (from 1.17 g/100 g dw to 0.91 g/100 g dw and from 4.42 g/100 g dw to 3.77 g/100 g dw respectively) due to leaching of minerals during soaking as a result of mineral solubilization (Agume et al., 2017). Soaking slightly only slightly decreases the ash content of steeped maize and steeped soybeans meanwhile the ash content is not affected by the roasting procedure, as they do not take part in Maillard's reaction.

Table 3: Proximate composition (expressed in g/100 g dry weight basis) of maize flour, soybean flour and cocoa powder as affected by their pretreatment type

Chemical composition	**Maize**		**Soybeans**			**Cocoa beans**		
	Raw	Soaked	Raw	Soaked	Roasted	Raw	Roasted	Defatted
Dry matter (%)	89.92 ± 0.31[a]	90.53 ± 0.52a	88.77 ± 0.71[b]	90.50 ± 2.39[b]	92.89 ± 0.90[a]	89.54 ± 2.06[b]	92.64 ± 0.23[a]	93.41 ± 1.25[a]
Moisture content* (g/100 g WB)	10.074 ± 0,31[a]	9.46 ± 0.52[a]	11.22 ± 0.71[b]	9.50 ± 2.39[b]	7.11 ± 0.90[a]	10.46 ± 2.07[b]	7.36 ± 0.23[a]	6.59 ± 1.25[a]
Soluble sugars content	1.71 ± 0.65[c]	5.39 ± 1.08[b]	1.54 ± 0.24[a]	1.59 ± 0.12[a]	1.51 ± 0.35[a]	5.13 ± 0.56[a,b]	3.95 ± 0.04[a]	4.37 ± 0.35a
Total carbohydrates content	72.73 ± 2.64[a,b]	69.64 ± 7.34[a]	23.90 ± 1.07[c]	22.21 ± 1.02[c,d]	20.25 ± 3.6[b]	23.89 ± 0.39[c]	22.72 ± 2.1[b]	24.93 ± 1.67[c]
Proteins content	8.78 ± 1.94[c]	8.36 ± 0.39[b]	31.75 ± 3.15[d]	29.69 ± 3.40[d]	27.68 ± 1.93[c]	19.87 ± 0.39[c]	19.21 ± 2.64[b]	21.70 ± 2.99[bc]
Lipids content	2.19 ± 0.01[a,b]	2.13 ± 0.25[a]	13.20 ± 0.91[b]	18.67 ± 2.12[c]	21.44 ± 0.39[b]	48.52 ± 3.83[d]	50.23 ± 1.27[c]	17.41 ± 3.04[b]
Ash content	1.17 ± 0.01[a,b]	0.91 ± 0.28[a]	4.42 ± 0.41[a]	3.77 ± 1.23[a,b]	3.40 ± 0.12[a]	3.23 ± 0.42[a]	4.64 ± 1.70[a]	3.45 ± 0.35[a]

Mean ± standard deviation; values with different letters within the same row differ significantly ($p < 0.05$) as determined by Duncan's multiple range test ($n = 3$). * Moisture is expressed based on fresh weight.

3.2. Proposed models

A simplex centroid mixture design was used to obtain our optimal mixture according to the specifications. The following models for the two responses (Y1 and Y2) have been obtained before optimization which are special cubic models

$$\boldsymbol{Y1 = 387.96x_1 + 530.50x_2 + 527,86x_3 - 0.06x_1x_2 - 0.06x_1x_3 + 337.58x_2x_3 + 0.37x_1x_2x_3} \quad (3)$$

$$\boldsymbol{Y2 = 70.99x_1 + 29.99x_2 + 20.95x_3 - 40.18x_1x_2 - 52.77x_1x_3 - 307.98x_2x_3 + 316,31x_1x_2x_3} \quad (4)$$

3.2.1. Validation of the models

To validate models of the predicted value, validation parameters (coefficient of determination, adjusted coefficient of determination, bias factor) were used shown in table 4. The adjusted coefficients of determination of Y1 and Y2 are greater than 0.8 (0.92 and 0.85 respectively) and their bias factor are closed to 1 (0.97 and 0.91). From these results, we can conclude that the two proposed models are can be considered as valid since the parameter of validation are closed to the values for standard models. These models can well fit to describe at 95 % confidence the behavior of the responses.

Table 4: Statistical validity of models and response specifications

Responses	Validation parameters			Measured value		Specifications
	R^2	Adjusted R^2 (> 0.8)	B_f [0,75 - 1,25]	Minimum	Maximum	
Y1 (Energy in kcal)	0.961	0.923	0.97	387.973	613.612	≥400
Y2 (Viscosity in Pa.s)	0.942	0.852	0.91	0.317	0.720	<1

3.2.2. Experimental and predicted value of the responses

Results of the experimental and predicted value are given in table 5. It can be observed that the measured value of Y1 on the experimental value are slightly different to the calculated value whereas there is a significant difference between the measured and calculated value. Statistical analysis and validation parameter calculation were done to justify the correlation between actual and predicted value and enable us to calculate the response for any chosen factor in the experimental domain.

Table 5: Measured value of the responses on the experimental points

Run	Factors			Responses			
				Y1 (Energy in kcal)		Y2 (Viscosity in Pa.s)	
	x_1	x_2	x_3	Actual	Predicted	Actual	Predicted
1	0.7	0.1	0.2	457.92	456.90	0.5190	0.5308
2	0.7	0.2	0.1	459.25	457.22	0.5770	0.5640
3	0.6	0.2	0.2	613.61	614.58	0.4640	0.4668
4	0.6	0.1	0.3	527.88	526.86	0.3170	0.3358
5	0.73	0.13	0.13	444.33	442.41	0.5340	0.5293
6	0.67	0.17	0.17	519.76	520.62	0.3400	0.3574
7	0.63	0.13	0.23	542.39	541.49	0.4200	0.4578
8	0.63	0.23	0.13	543.71	543.81	0.4230	0.4350
9	0.6	0.3	0.1	530.52	531.50	0.6500	0.6341
10	0.8	0.1	0.1	387.97	388.96	0.7200	0.7230
11	0.67	0.17	0.17	521.91	522.21	0.3410	0.3587
12	0.67	0.17	0.17	517.02	.81	0.3440	0.3552
13	0.67	0.17	0.17	523.12	521.05	0.3200	0.3470

3.2.3. Significance of the effects of factors

Table 6 presents the estimate coefficients of the two models, the standard errors on the coefficients and the significance of the terms of each model, through the P-values. Table 6 makes it possible to assess the importance of the significant effects on the responses, in particular the effects of significant factors and interactions.

Table 6: Coefficients values and significance of energy and viscosity model terms.

	Energy			Viscosity		
	Coeffiicient	Standard error	P-value	Coeffiicient	Standard error	P-value
x_1	387.96	0.1247	<0.0001	**70.99**	0.104	<0.0001
x_2	530.50	0.1247	<0.0001	**29.99**	1.256	<0.0001
x_3	527.86	0.1247	<0.0001	**20.95**	1.256	<0.0001
x_1x_2	**-0.06**	0.6278	0.032	-40.18	2.307	0.017
x_1x_3	**-0.06**	0.6278	0.0083	-52.77	2.307	0.010
x_2x_3	337.58	0.6278	0.0001	-307.98	12.22	0.046
$x_1x_2x_3$	0.37	4.1400	0.0337	**516.31**	19.94	0.081

Table 6 shows that P-values of the direct factors and those of the interactions for both energy and viscosity are less than 0.05, indicating that the model terms are significant, except that of the triple interaction of viscosity which is greater than 0.05 indicating that the term is not significant.

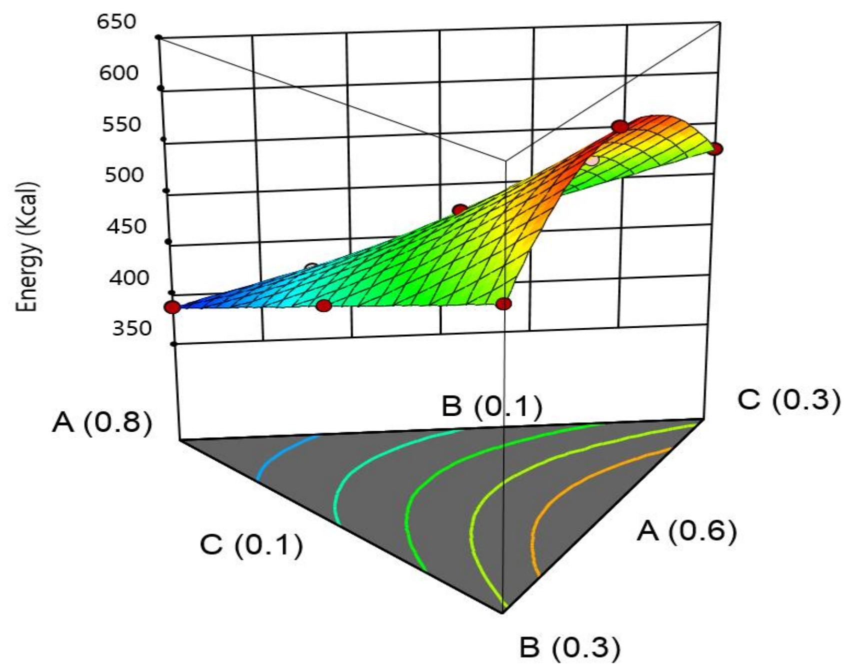

Figure 2: Contour plots showing the effects of factors on the energy value

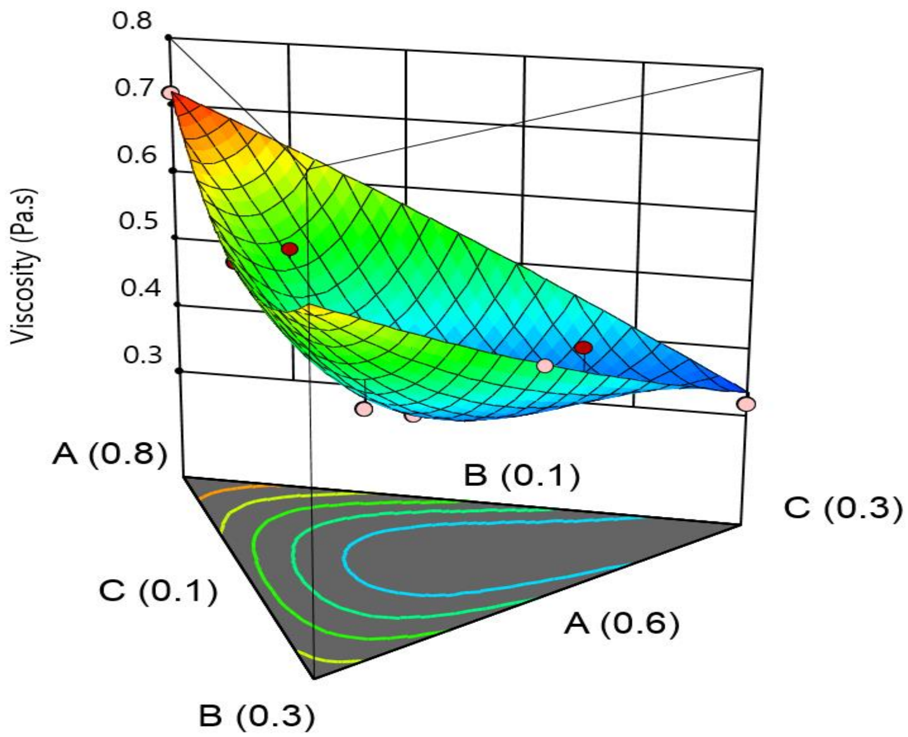

Figure 3: Contour plots showing the effects of factors on the apparent viscosity

Concerning the influence of the coefficient of each term on the energy (Figure 2), the double interactions x_1x_2 and x_1x_3 all have the same and negative effect on the energy value. Meanwhile the double effect x_2x_3 and triple effect $x_1x_2x_3$ alongside with factor x_1, x_2, x_3 all have positive effect on the energy with the double effect x_2x_3 having the higher effect of interactions (337.58). The term factors equally have great effect in improving the energy value with $x_1$and x_2 having the highest effect (530.50 and 527.86 respectively). P-values of the interactions are all less than 0.05 indicating that the model term are significant.

Concerning the effect of the coefficient of the model term on the viscosity (Figure 3), the double interactions x_1x_2, x_1x_3 and x_2x_3 have negative effects on the response with x_2x_3 having the highest effect (12.22). Whereas term facrors x_1, x_2, x_3 and triple effect $x_1x_2x_3$ all have positive effect on the viscosity the triple effect having the highest effect on the response (19.94) and the term factor x_1 having the least effect on the response (0.104). P-values of the interactions are less than 0.05 indicating that the model term are significant except that of the triple interaction which is greater than 0.05 indicating that the term is not significant.

3.3. Optimization of responses

The simultaneous optimization of the responses (Energy value and viscosity) was done by combining the experimental factors (steeped maize: x_1 , steeped soybeans: x_2 and roasted cocoa: x_3) and maximizing the desirability function. The optimal points of the two responses were gotten experimentally and range of the specifications were found in these value implying that the responses can be optimized.

Two solutions are obtained from the optimal zone with their desirabilities representing the maximum and minimum points on the specifications. These points represent the practicals points atwhich the solution can be validated.

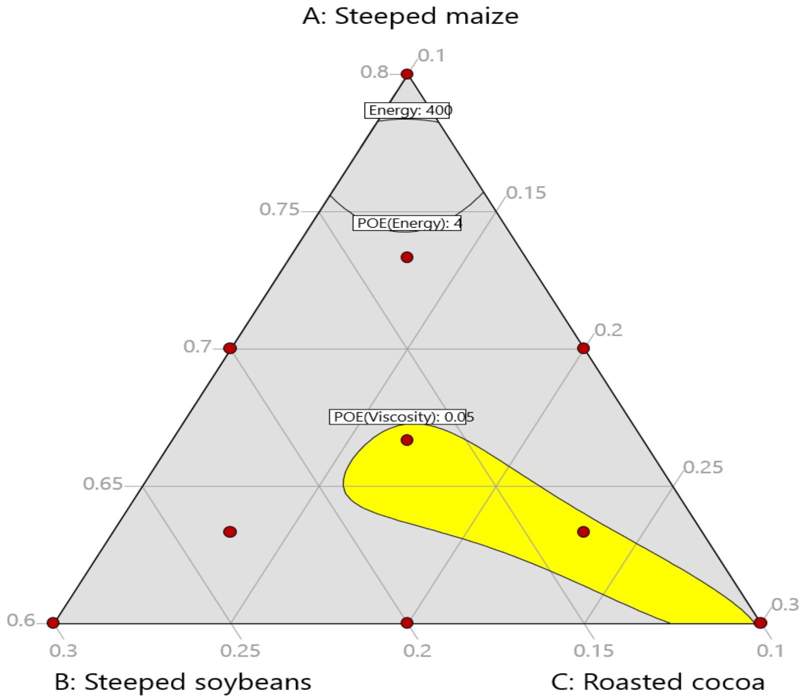

Figure 4: Acceptability area obtained by overlaying the contour plots of energy value and apparent viscosity respecting the desired gruel properties.

Table 7: Desirability of the solution found

N°	SM	SS	RC	Energy (kcal)	POE (Energy)	Viscosity (Pa.s)	POE (Viscosity)	Desirability
1	**0.618**	**0.133**	**0.248**	**556.418**	**6.896**	**0.360**	**0.050**	**0.734**
2	0.600	0.117	0.283	548.028	7.359	0.350	0.050	0.677

SM: Steeped maize; **SS**: Steeped maize**; RC:** Roasted cocoa; **POE**: Propagation of errors

3.4. Validation of the optimum

The point with the highest desirability (0.734) were chosen and tested to verify so as to validate the optimal solution. Table 7 enables us to verify if the conditions given by the specifications. A flour mixture ratio made up of 0.62 steeped maize, 0.13 steeped soybeans and 0.25 was used for the verification and compared with the theoretical values. The viscosity obtained experimentally is 0.31 ± 11 Pa.s with and energy value 545.16 ± 1.15. The conclusion is that the optimal point can be used for the formulation of an infant gruel.

Table 7: Comparison between the theoretical and measured optimal solution

		Theoretical value	Measured value	Specifications		Units
				Lower bound	Upper bound	
Factors	SM	0.62	0.62	0.6	0.8	-
	SS	0.13	0.13	0.1	0.3	-
	RC	0.25	0.25	0.1	0.3	
Responses	Energy	556.42^{a}	545.16 ± 1.15^{a}	400	-	kcal
	Viscosity	0.36^{a}	0.31 ± 0.11^{b}	-	1	Pa.s

Mean ± standard deviation; values with different letters within the same line differ significantly ($p < 0.05$) as determined by Duncan's multiple range test (n = 3).

4. CONCLUSION

The aim of this work was to evaluate the influence of pretreatment on the composition and flow behaviour of maize, soybeans and cocoa infant gruels. Firstly, the effect of pretreatment on the composition was determined and then, the best flours from each material were used for the mixture design. This work reveals that steeping greatly improved on the soluble sugars content of maize and soybeans while roasting improved on the availability of lipids thereby fluidifying the gruel. Roasting led to an increase in the lipids content of soybeans and cocoa beans and a decrease in their protein content.

Total carbohydrate and protein content in defatted cocoa was higher than that of roasted cocoa. The data analysis obtained from the mixture design enabled us to validate the polynomial model proposed. The optimal mixture point obtained according to the specifications (viscosity ≤ 1 Pa.s and energy value ≥ 400 kcal/100 g MS) were at the point 0.62 for steeped maize, 0.13 for steeped soybeans and 0.25 for roasted cocoa beans given a gruel viscosity of 0.31 Pa.s and an energy value of kcal. gruel.

5. CONFLICTS OF INTERESTS

None to declare.

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