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Optimization of the Production of a Chocolate-flavoured, Soy-peanut beverage with acceptable Chemical and Physicochemical Properties using a Three-component Constrained Extreme Lattice Mixture Design

Henry Mensah-Brown[1*], Emmanuel Ohene Afoakwa[2] and Winifred Boahemaa Wadie[2]
[1]Department of Food Process Engineering, University of Ghana, Legon-Accra, Ghana
[2]Department of Nutrition & Food Science, University of Ghana, Legon-Accra, Ghana
*Corresponding author: hmbrown@ug.edu.gh / hmbrown55@gmail.com

Abstract

This study explored the feasibility of producing a soy-peanut, chocolate-flavoured milk beverage with acceptable chemical and physico-chemical properties from soybeans, peanuts and cocoa powder. Ten formulations were processed by mixing three basic ingredients: soybeans (20g/100g-80g/100g), peanuts (*Arachis hypogaea L.*) (20g/100g-60g/100g) and cocoa powder (1g/100g-7g/100g). The optimized proportions of the ingredients were obtained using a three-component, constrained extreme lattice mixture design. The optimized product consisted of 54.0-58.5% soybeans, 37.0-42.0% peanut and 4.46 - 4.48% cocoa powder and had an energy value of 124.103kJ/100g. Proximate analysis of the optimized products indicated that the beverage has a protein content of 2.77%, fat content of 1.38%, carbohydrate content of 1.26%, ash content of 0.32% and water content of 94.27%. This suggests that production of an acceptable full fat soy-peanut, chocolate-flavoured milk beverage is feasible through the optimization of the basic ingredients.

Keywords: lattice mixture design, soybeans, peanuts, cocoa powder, soy-peanut, chocolate-flavoured milk beverage.

1. Introduction

Milk–like beverages manufactured from oilseed preparation have a great potential as nutritional substitutes, especially in cultures where cow milk is in insufficient quantity, too expensive or indigestible (Schmidt and Bates, 1976, Isanga and Zhang, 2009). Current studies show that many oilseeds beverages or blends of oilseed with cow milk have been employed with a degree of satisfaction in some cultures. Diarra *et al*. (2005) suggested that the current renewed interest in vegetable milk as well as products made from it may be due to the growing awareness of the nutritional benefits of plant-based foods by health conscious consumers. The major legumes that have been used in vegetable milk products include soybean, cowpea, winged bean, peanut and melon seeds (Senayah, 1993).

Generally, legumes and oilseeds have characteristics that make them convenient to combine two or more to obtain an acceptable product (Aidoo *et al*., 2010). In particular, peanut is known to be higher in energy compared to cowpeas which is lower in energy (Akinyele and Abudu, 1990) and Asiamah (2005) suggested that combining the two effectively complemented each other. In addition, Nadutey (1999) found that composite products made using peanut-cowpea blends were found to have minimal beany flavour, compared to the strong beany flavour of cowpea milk alone. In view of this products such as coffee creamers have been made from soy and peanut milk (Mulando and Resurreccion, 2006).

Soy milk is a rich creamy liquid with a nutty flavour which is found to be nutritionally comparable to cow milk in most respects. Nevertheless, the beany flavour of soy is still the main characteristic responsible for its low acceptability in occidental countries (Carrão-Panizzi *et al*., 1999). Soy-based products are often described as bitter, rancid and astringent (Hajirostamloo, 2009) hence, the use of flavours such as, strawberry, vanilla, coffee and chocolate to mask the beany flavour. However, it is challenging to provide nutritious food that ensures appealing taste, texture and appearance hence the need for optimizing all aspects of the production in an effective way to accomplish a successful development of the product (Deshpande *et al*., 2008).

The main objective of the study was to optimize the use of soybeans, peanuts and cocoa powder for the production of a chocolate-flavoured, soy-peanut beverage with acceptable chemical, and physico-chemical properties employing a three-component constrained extreme lattice mixture design.

2. Materials and Methods

2.1 Materials

Soybeans of the Jenguma variety and peanuts of the Chinese variety were used in this study. These were obtained from the Madina market in Accra. The soy lecithin and gum-based stabilizer (carrageenan) were obtained from the Cocoa Processing Company, Tema and Healthy Life Fruit Juice Company, respectively. The cocoa powder and sugar were obtained from the Melcom and Max Mart supermarkets in Accra.

2.2 Experimental design

A three-component constrained extreme lattice mixture design (Cornell, 1983) was used. The mixture components consisted of soybeans (X_1), peanuts (X_2) and chocolate (X_3) which made up 100% of the total formulation. All formulations contained 5.5% sugar, 3% carrageenan and 30% added soy lecithin. Component proportions were expressed as fractions of the mixture and the sum (X_1+X_2+X_3) proportions equalled one. The practical range of proportions of component variables (X_1, X_2 and X_3) was established based on solid content (Fig. 1 and Table 1). Minitab Release 14 software was used to design the experiments, analyse the results and generate the contour plots for the various physico-chemical properties of the chocolate-flavoured, soy-peanut beverage produced. Data obtained from the physico-chemical and chemical analyses were analyzed using ANOVA and LSD in Statgraphics plus (version 3.0). Figure 1 shows the constrained region in the simplex coordinate system. Table 1 gives the compositional ratios of ten possible formulations used in the experiments while Table 2 gives the lower and upper limits of compositional ratio of chocolate-flavoured, soy-peanut beverage.

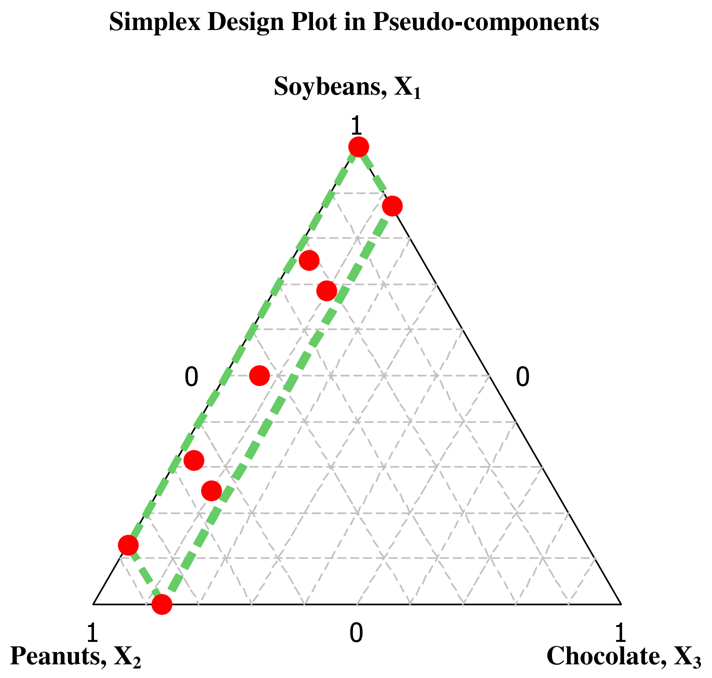

Figure 1. Constrained region in the simplex coordinate system
The red dots represent the ten formulations and these correspond with the numbers in Table 1.

2.3 Sample preparation

Raw soybeans and peanuts were cleaned by hand picking out all the dirt and other extraneous materials like stones, stalk pieces and bean husks. The cleaned peanuts were light roasted for 10 minutes to facilitate the removal of the hulls. The seeds were dehulled by passing them through an attrition disc mill set loosely to remove the seed coats. The cotyledons were separated from the hulls using the floatation method. The cotyledons were then soaked in 2% sodium hydrogen bicarbonate ($NaHCO_3$) solution for 3 hours. The peanut seeds were then washed with cold water to remove residual $NaHCO_3$. The soybeans were then soaked in 2% ($NaHCO_3$) for 18 hours, wet blanched in boiling water at 100°C for 10 minutes, cooled with tap water and then washed with cold water to remove residual $NaHCO_3$. The soybeans, peanuts and chocolate powder were weighed separately and milled with cold water using a Philips blender in the ratio 1:7 that is 1 part of soybeans, peanuts and chocolate powder to 7 parts of water. The three components were blended together for 105 seconds. The slurry obtained was filtered using a clean cheese cloth and homogenized. This was followed by the addition of the lecithin and gum based stabilizer at a temperature of 80°C. Sugar was added to taste. The milk obtained was then cooked for 15 minutes in the jacketed pan. The samples were filled into sterilized bottles and corked. The bottles were sterilized by boiling them in clean water for 30 minutes and storing them in 2ppm sodium bisulphite solution. The milk samples were pasteurized at 100°C for 30 minutes, cooled and refrigerated.

Table 1. Compositional ratio of ten possible formulations

Formulation	Proportion of ingredient (%)		
	Soybeans	Peanuts	Chocolate
1	56.0	40.0	4.0*
2	64.5	30.0	5.5
3	47.5	50.0	2.5
4	44.5	50.0	5.5
5	79.0	20.0	1.0
6	67.5	30.0	2.5
7	73.0	20.0	7.0
8	39.0	60.0	1.0
9	33.0	60.0	7.0
20	56.0	40.0	4.0*

* Formulation in the middle was repeated to obtain the ten formulations.

Table 2. Lower and upper limits of compositional ratio of beverage

Component	Lower limit	Upper limit
Soybean	20	80
Peanuts	20	60
Chocolate	1	7

2.4 Analytical Methods

2.4.1 Proximate composition

Moisture, protein and ash content of the samples were determined using the AOAC (1990) methods. Fat content was determined using the Gerber method AOAC (2001) method 200.18. Carbohydrate was determined by difference. The caloric values were calculated using the expression:

$$EV(KJ/100g) = [(\%AC \times 17) + (\%P \times 17) + (\%F \times 37)]; \qquad (1)$$

where, EV = Energy value of food; $\%AC$ = Percentage carbohydrates; $\%P$ = Percentage protein; $\%F$ = Percentage fat.

2.4.2 Physico-chemical properties

Physico-chemical properties of the chocolate flavoured soy-peanuts beverage determined in this study included pH, titratable acidity, total solids content, colour and apparent viscosity.

2.4.3 Determination of pH

The pH of the beverage was determined using a pH meter (Model pHep3, MicropHep).

2.4.4 Titratable acidity

Titratable acidity was determined using AOAC method 947.05 (AOAC, 1990). Five millilitres (5ml) of beverage was mixed with 25ml carbon dioxide free water and the mixture was then titrated against 0.1M NaOH using 1% phenolphthalein as indicator. The determination was done in triplicate and acidity was calculated as lactic acid (90g/100ml).

2.4.5 Total solids determination

The total solids content was determined using an Abbe refractometer according to the AOAC approved method 16.032 (AOAC, 1975).

2.4.6 Apparent viscosity

A Brookfield digital viscometer (Model DV-1; Brookfield Engineering Labs Inc., Middleboro, USA) was used for the viscosity determinations. The spindle used was an LV spindle, with a spindle number of 2.

3. Results and Discussion

3.1 Effect of the ingredients on the total solids content of the soy-peanut beverage

Results for total solids of the ten formulations differed significantly. Total solids which refer to how much solids are dissolved in a given medium increased with increasing proportions of cocoa powder as can be observed from the contour plot (Fig. 2). High levels of soybeans and peanut gave rise to products with low total solids. The decreasing solid content with increasing levels of peanut and soybeans may be due to the high fat content of the seeds which affects the solubility of the proteins.

3.2 Effect of the ingredients on the viscosity of the soy-peanut beverage

The viscosity of the beverage varied with each formulation. Differences in the viscosity were statistically significant ($p \leq 0.05$). With reference to the contour plot (Fig. 3) it was observed that increasing the amounts of cocoa powder in the product increased its viscosity since the soluble solid content of cocoa powder is higher than that of the vegetable milk. Tamime and Robinson (1999) reported that higher total soluble solid content in milk usually increases the viscosity and consistency of the end product.

3.3 Effect of the ingredients on the pH and titratable acidity of the soy-peanut beverage

Although both pH and titratable acidity measure the sourness of the beverage, pH is a measure of the hydrogen ions (H^+) activity in solution whilst titratable acidity measures the predominant acid present in the beverage. For peanut and soybeans titratable acidity was measured as percent lactic acid. The pH of the formulations ranged from 6.863 to 8.078. The slightly acidic to basic pH was due to soaking in sodium bicarbonate. At a confidence level of 95.0%, all nine formulations showed significant differences**.** The mixture contour plot (Fig. 4) showed that pH increased with increasing amount of soybeans and peanuts in the formulation. This is due to the increasing amount of proteins contributed as the amount of peanuts and soybeans increased. The pH of the cocoa powder was 5.83±0.04, and this could not account for the high pH values obtained. R^2 adjusted was 33.02%. The regression model obtained for the pH of the soy-peanut chocolate flavoured beverage was:

$$Y = 8.79\,X_1 + 13.05\,X_2 - 35.65X_3 - 12.60\,X_1\,X_2 + 58.12X_2X_3,\ R^2 = 33.02\%; \qquad (2)$$

where, X_1 = Soybeans, X_2 = Peanuts and X_3 = Chocolate.

The predictive model for titratable acidity could account for 8.11% of the variations in the data. From Fig. 5 below it was observed that percent titratable acidity decreased with increasing amount of the soy and peanuts in the product but increased with increasing cocoa powder. The processing of cocoa beans involves fermentation by lactic acid bacteria and this perhaps accounts for the increasing acidity values with increasing cocoa powder. The regression model obtained for the titratable acidity of the soy-peanut chocolate flavoured beverage was:

$$Y = 0.34\,X_1 - 0.08\,X_2 + 6.15X_3 - 10.53X_2X_3,\ R^2 \text{ adjusted} = 8.11\%; \qquad (3)$$

where, X_1 = Soybeans, X_2 = Peanuts and X_3 = Chocolate.

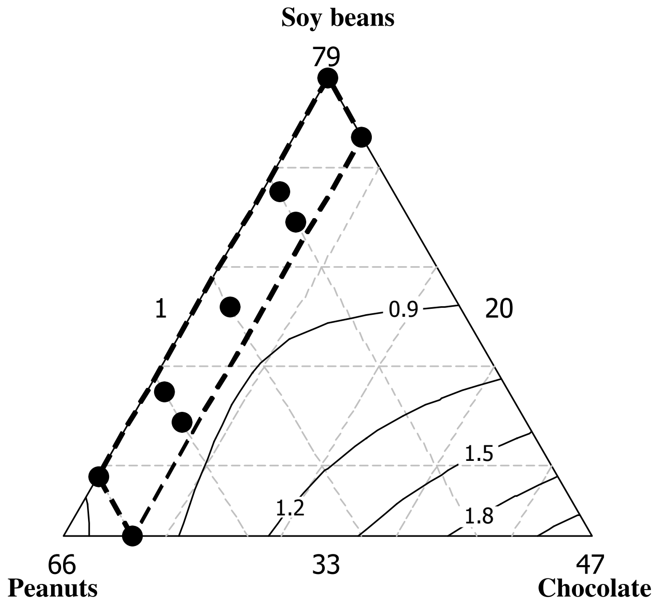

Figure 2. Mixture contour plot of Total solids

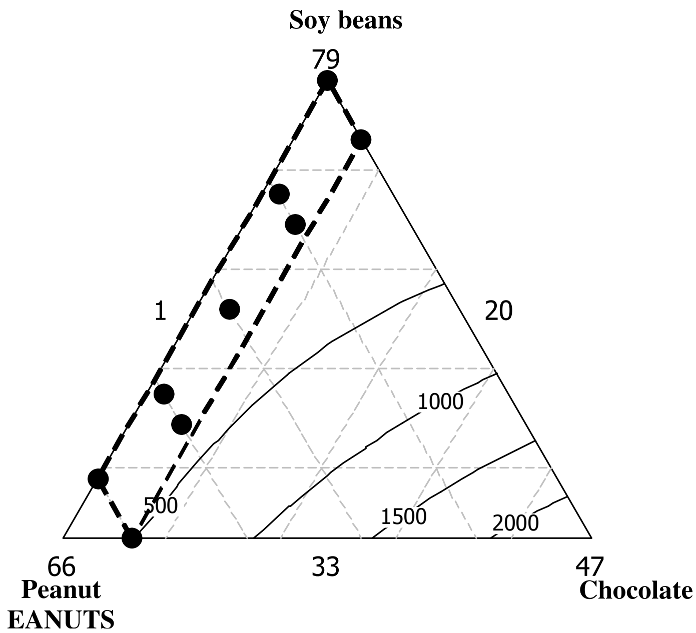

Figure 3. Mixture contour plot of viscosity

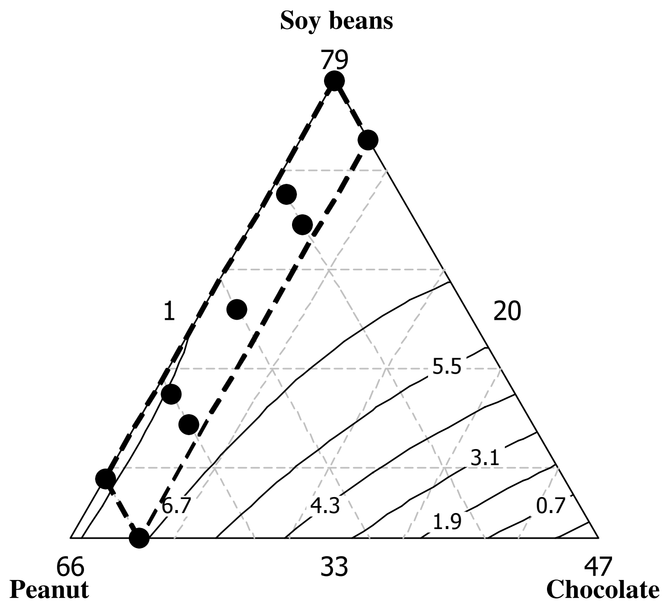

Figure 4. Mixture contour plot of pH

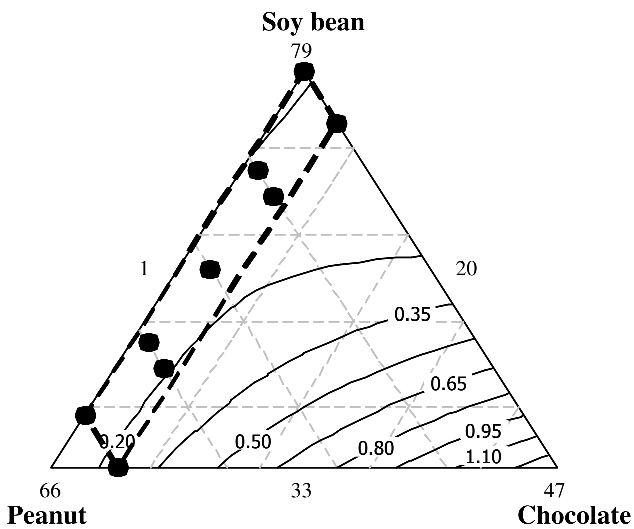

Figure 5. Mixture contour plot of titratable acidity

3.4 Effect of the ingredients on the microbial safety of the soy-peanut beverage

Microbiological analysis of all nine formulations showed that the products were free of Coliforms as well as yeast and moulds after incubating at 37°C for 24 hours and at 24°C for 48 hours, respectively. However, growth of aerobic microorganisms was observed at a dilution factor of 10^{-1} for all the formulations with the exception of formulations 5, 6, 7 and 9. Nevertheless, results obtained corresponded with standards set by Ghana Standard

Authority (GS 725:2003). The low microbial load was due to the use of sodium disulphite (2ppm). The bottles after sterilizing for 30 minutes were kept in a sodium bisulphite solution.

3.5 Nutritional composition of optimized products

Two formulations were selected from the optimum region and proximate analysis was carried on both formulations. Table 3 shows the compositional ratios of each formulation. The nutritional composition of the soy-peanut, chocolate-flavoured beverage is presented in Table 4. The nutritional composition of soy and peanut milk from literature has been presented alongside for easy comparison.

Table 3. Compositional ratio of products from the optimized region

Composition (%)	Optimum product 1	Optimum product 2
Soybeans	58.30	54.01
Peanuts	37.21	41.42
Cocoa powder	4.48	4.46

3.6 Carbohydrate

Carbohydrate in nutritional labelling is important because it serves as a source of energy. The carbohydrate content of the soy-peanut beverage was low compared to just soymilk and peanut milk from literature. Differences in the carbohydrate content between product 1 and 2 were not significant. Product 1 had a carbohydrate content of 0.98% whereas product 2 had a carbohydrate content of 1.542%.

Table 4. Proximate composition of optimized (final) products compared to literature values for soy and peanut milk (100g)

Composition	Type of milk				
	Optimum product 1	Optimum product 2	Average	Literature soy milk‡	Literature peanut milk§
Energy (kJ/100g)	106.654	141.551	124.103	149	258
Water (%)	94.745 (0.42)	93.79 (0.48)	94.268	92.5	90.0
Protein (%)	2.682 (0.01)	2.853 (0.06)	2.768	3.4	2.1
Fat (%)	1.2 (0.00)	1.55 (0.00)	1.38	1.5	4.4
Carbohydrate (%)	0.98 (0.42)	1.542 (0.552)	1.26	2.1	3.5
Ash (%)	0.367 (0.06)	0.267 (0.06)	0.317	0.5	0.02

‡Nadutey (1999) and §Sanni *et al*. (1999)

3.7 Protein

Proteins are important for all biological functions and cell structure (USDA, 2005). As much as 2.853g/100g of protein was extracted from the soy-peanut, chocolate-flavoured beverage. This was lower than the protein content of soymilk as stated by Nadutey (1999) and Sanni *et al*. (1999); and relatively higher than the protein content of peanuts stated in literature. The relatively low protein content of the peanuts may have further decreased the total composition in the final mixture. Some proteins are not water soluble therefore could not have been extracted.

3.8 Fat

Fat serves as a main source of energy in any given feed, thus the fat content of the product is of uttermost importance. Peanuts are known to contain about 49.24% fat (USDA, 2005). Therefore, the relatively high fat content observed in product 2 was due to a higher peanut content in the formulation. The fat content of the soy-peanut beverage was much lower than the fat content of peanut milk obtained from literature, Sanni *et al*. (1999). Fat is soluble in organic solvents like petroleum ether. However, water was used in extraction in this study thus accounting for the low fat content.

3.9 Ash

The ash content represents the total mineral content in foods and refers to the inorganic residue remaining after ignition or complete oxidation of organic matter in a food product. The ash contents of the two optimum products were not significantly different. The ash content compared to that of soymilk from literature was lower. Differences in the nutrient composition of beverages from literature and that obtained in this experiment may be due to the differences in the water content, experimental method used and the variety of soy and peanuts used. In addition, minerals may have leached out due to the long soaking hours (Liu, 1997). Liu (1997) reported that on the average, soaking beans for 24 hours resulted in a 5% loss of solids.

Physico-chemical analysis of two of the product from the optimized region showed a neutral pH and a titratable acidity value of 0.198 to 0.258%. From the Table 5, it can be observed that acidity increased as pH decreased. Significant differences were observed between the products for both pH and titratable acidity. Differences in pH and titratable acidity were due to differences in the formulations.

Values for soluble solids ranged from 7.05 to 8.05. Optimum product 2 obtained a higher brix value. The higher brix value of product 2 may have contributed to its high viscosity value. Differences in brix and viscosity were statistically significant.

Table 5. Physico-chemical properties of products from the optimized region

Physico-chemical property	Optimized product 1	Optimized product 2
pH	7.3430 (0.0058)	7.2300 (0.0436)
Titratable acidity (%)	0.1980 (0.0000)	0.2580 (0.0001)
Brix (^{o})	7.0500 (0.0000)	8.0500 (0.0000)
Viscosity (cp)	80.0000 (8.6850)	86.4000 (6.7273)

4. Conclusion

The results showed an optimum region generated from the superimposition of the regions of acceptance. The proximate analysis of the optimized products revealed the beverage has an energy value of 124.103kJ/100g, water content of 94.27%, protein content of 2.77%, fat content of 1.38%, carbohydrate content of 1.26% and ash content of 0.317%. The products from the optimized region had a neutral pH, titratable acidity ranging between 0.198%-0.258%, brix 7.05^o-8.05^o and viscosity 80.0-86.4cp. The microbial quality of product met standards set by the Ghana Standard Authority. It is therefore feasible to optimize the production of a full fat soy-peanut, chocolate-flavoured milk beverage using a three-component constrained extreme lattice mixture design. The optimization procedure developed here can be used for the formulation and production of chocolate-flavoured milk beverage comprising of soy-peanut and cocoa powder in industry. Further research work will include sensory evaluation and overall acceptability of soy-peanut chocolate-flavoured milk beverage on the Ghanaian market.

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