



Development and characterization of dehydrated peanut–cowpea milk powder for use as a dairy milk substitute in chocolate manufacture

Herta Aidoo^a, Esther Sakyi-Dawson^b, Kwaku Tano-Debrah^b, Firibu Kwesi Saalia^{b,*}

^a Cocoa Processing Company Ltd., Private Mail Bag, Tema, Ghana

^b Department of Nutrition and Food Science, P.O. Box LG 134, University of Ghana, Legon, Accra, Ghana

ARTICLE INFO

Article history:

Received 11 March 2009

Accepted 25 August 2009

Keywords:

Peanut–cowpea milk
Chocolate
Functional properties
Friedman test

ABSTRACT

This study explored the feasibility of producing peanut–cowpea milk for use in vegetable milk chocolates. Development of the vegetable milk followed a 3×2 factorial design, with peanut–cowpea ratio (1:1, 1:2 and 1:3), and treatment with enzyme (i.e. enzyme hydrolyzed and non-hydrolyzed milk) as the factors. The milk was dehydrated and then milled using a hammer mill (mesh size 40). It was then used in recipes to produce chocolates and evaluated sensorially based on ranking for preference. Skimmed milk powder was used to produce the control chocolate. The ratio of cowpea to peanut affected the chemical and functional characteristics of the vegetable milk. Vegetable milk made from 1:2 ratios of peanuts:cowpea produced the most preferred chocolates. The successful application of this by industry will improve the utilization of the legume crops and enhance their market value.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

The production of vegetable “milk” using legumes and oil seeds is an old technology that dates back to the 13th century (Smith & Circle, 1972). In time the technology has been improved to include development of vegetable alternatives to dairy milk especially in the formulation of infant foods because they are high in protein, minerals and vitamins. The major legumes that have been used in vegetable milk production include soybean, cowpea, winged bean, groundnut and melon seeds or “agushie” (Nelson, Steinberg, & Wei, 1976; Senayah, 1993).

Current renewed interest in vegetable milk and products made using it is because of the growing awareness of the nutritional benefits of plant-based foods by health conscious consumers (Diarra, Nong, & Jie, 2005). Consequently soy and peanut milk have been used in a variety of milk-based products including coffee creamers (Mulando & Resurreccion, 2006), and chocolate milk drink (Deshpande, Chinnan, & Phillips, 2008). Legumes and oil seeds have characteristics that make it convenient to combine two or more to obtain an acceptable product. In particular, peanut milk is known to be high in energy, whereas cowpea milk on its own has low energy (Akinyele & Abudu, 1990). Combining the two effectively removed these limitations (Asiamah, 2005). Furthermore, it has been demonstrated that cowpea milk has a strong beany flavour while peanut–cowpea composite blends have minimal beany flavour (Nadutey, 1999). A composite product made

using peanuts and cowpeas as sources of nutrients such as protein, dietary fibre, folate and other vitamins and minerals would be an ideal dairy milk substitute. Vegetable milk made from peanut and cowpea blends could be dehydrated to produce an inexpensive dry milk powder. Indeed Chandrasekhara et al. (1964) reported spray drying of peanut milk combined with other sources of milk, and the powder could be reconstituted in water. The objective of this study was to develop a dehydrated peanut–cowpea “milk” that would be acceptable for the production of milk chocolate.

2. Materials and methods

2.1. Raw materials

The most common variety of peanuts (*Arachis hypogaea*), locally called ‘Chinese’ variety, and cowpeas (*Vigna unguiculata*), were purchased from the local market in Tema, Ghana. Paddy rice (*Oryza sativa*) to be sprouted for use as a source of crude amylase for starch hydrolysis was obtained from the Irrigation Development Authority, Ashaiman, Ghana. The legume grains and the paddy rice were all sorted to remove moldy or discolored ones as well as any extraneous materials from the lot.

2.2. Sample pre-treatments

Weighed quantities of the peanuts were blanched by submerging in boiling water for 1 min, drained and then dehulled. To further ensure the removal of beany flavour in the final product, and to help soften the peanuts, the dehulled nuts were steeped

* Corresponding author.

E-mail address: fsaalia@ug.edu.gh (F.K. Saalia).

in 2% NaHCO_3 for 18 h, and then washed in clean water. Similarly, weighed samples of cowpeas were steeped in water for about 5 min and dehulled. The dehulled beans were then steeped in 2% NaHCO_3 for 3 h, and then washed in clean water (Asiamah, 2005).

2.3. Preparation of the dehydrated legume milk

2.3.1. Design of experiment

A 3×2 full factorial design was followed, and the factors were: (a) the ratio of peanut–cowpea (3:1, 2:1, 1:1) and (b) the application of enzyme (crude amylase) (i.e. enzyme treated and non-enzyme treated) vegetable milk.

Two different procedures were followed for making the vegetable milk as illustrated in the process flow chart in Fig. 1.

2.3.1.1. Procedure 1. The dehulled peanuts and cowpeas were combined in specific ratios according to the experimental design and slurried in a blender using a ratio of one part of grains to two parts of water. The slurry was further milled using a colloid mill (Premier 84, Premier Colloid Mills Ltd., Walton-on-Thames, Surrey, UK) to obtain a smooth, fine, homogenized milk. The milk was then dried using a drum dryer (R. Simon Dryers Ltd., Nottingham, England) operated at 40psi steam. The dehydrated milk flakes were milled to a fine powder with hammer mill equipped with a screen of mesh size 40.

2.3.1.2. Procedure 2. This procedure involved the addition of crude amylase enzyme extracted from the germinated paddy rice, on the

milk obtained from procedure 1. One (1) kilogram of sorted and cleaned paddy rice was weighed and steeped in 3 l of clean water for 12 h. It was drained and spread on wet, heat sterilized (by boiling) jute sacks. The grains were covered by a piece of jute sack and left to stand at ambient temperature (24–28 °C) for 4 days. During the germination period the set up was periodically (twice a day) sprinkled with water to keep it moist. The sprouted rice was harvested, de-vegetated and dried in an air oven (Precision Thelco ovens, Model 160 M, USA) set at 50 °C for 24 h. The dried malt was milled into powder using a hammer mill (Christy and Norris, Chemsford, England) equipped with mesh size 40. To obtain the enzyme, ice cold distilled water was added to weighed amounts of the milled rice malt and allowed to stand for 30 min with intermittent stirring. The slurry was centrifuged in a refrigerated centrifuge (4 °C) (TOMY Refrigerated Centrifuge – CX 250, Tokyo, Japan) at 8500g for 10 min. The supernatant, containing the crude enzyme was then filtered cold (8 °C) and stored in the refrigerator until it was used. The crude enzyme extract was mixed with part of the homogenized milk from procedure 1 (8% v/v) and held at 56 °C for 45 min. The enzyme treated milk was then dehydrated on the drum dryer.

From the two procedures six (6) different samples with peanut:cowpea ratios of 1:1, 2:1, 3:1 were obtained.

2.4. Proximate analyses of the dehydrated peanut–cowpea “milk”

Moisture content of the samples was determined by drying at 103 ± 2 °C overnight as per the air oven drying method (AOAC,

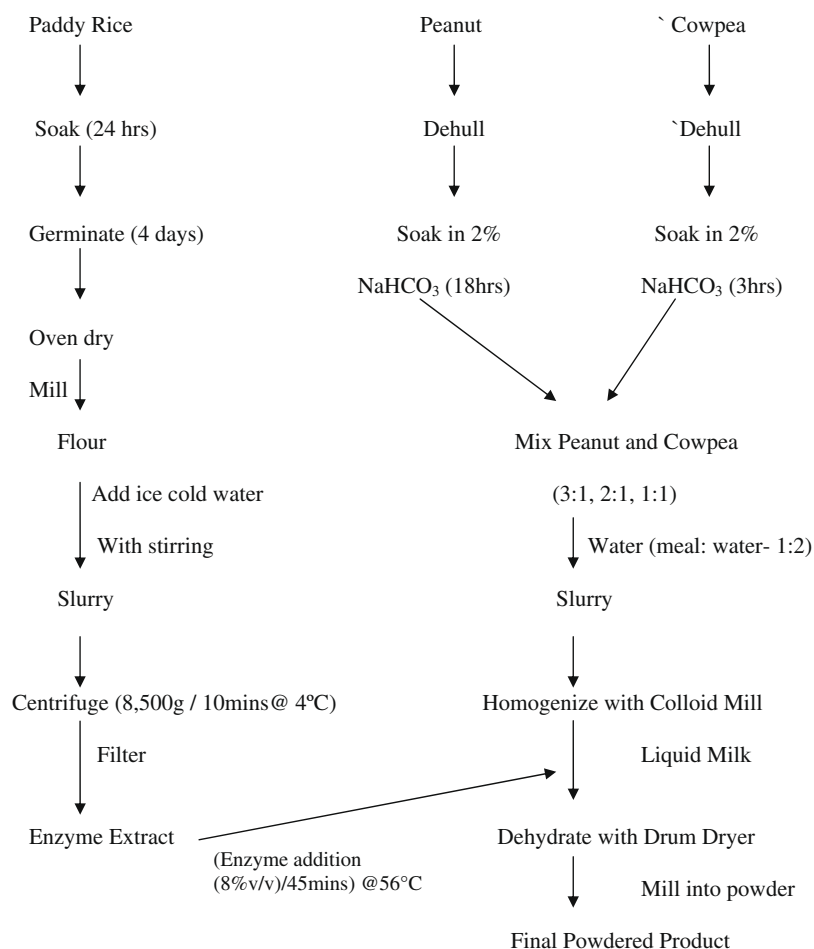


Fig. 1. Process flow chart for dehydrated peanut–cowpea milk.

1990). Ash content was determined using a Gallenkamp Muffle Furnace, England, (AOAC, 1990). Fat was determined in the soxhlet apparatus (AOAC, 1990) using petroleum ether as the solvent of extraction. The macro Kjeldahl procedure based on the AOAC method (AOAC, 1990) was used for nitrogen and the protein content of samples was calculated using 6.25 as the conversion factor. Crude fibre content was determined based on the procedure laid down in the Fertilizers and Feeding Stuffs (Amendment) Regulations 1976 SI No. 840 of Pearson's Chemical Analysis of Foods, (Egan, Kirk, & Sawyer, 1981).

3. Mineral analyses

The wet digestion method (AOAC, 1990) was used to eliminate all organic matter before samples were analyzed for the various minerals. Magnesium (Mg), Calcium (Ca), Zinc (Zn), Iron (Fe) were all determined using the PerkinElmer Atomic Absorption Spectrophotometer (AAS; Model AAnalyst 400, (Shimadzu, Japan). Phosphorus (P) was determined with the use of Milton Roy Spectrophotometer (Model Spectronic 301, Bie & Bernsten A.S, USA.). Sodium (Na) and Potassium (K) were determined with the use of the Jenway PFP 7 Flame Photometer (Daigger Instruments, USA).

3.1. Physicochemical characteristics of dehydrated milk

pH and titratable acidity was determined after dispersing 10.0 g of the dehydrated-product in 100 ml distilled water, allowing it to stand for 30 min and filtering. The pH was determined using a pH meter (Model HM-30S, TOA Instruments, Japan). Aliquots of the filtrate (10 ml) were titrated against 0.1 M NaOH using 1% phenolphthalein as indicator. Acidity was calculated as lactic acid (% m/v) as specified in the Quality Assurance Procedure Manual of Cocoa Processing Company Ltd., Tema, Ghana.

Reducing sugars were determined by the titration method of Lane and Eynon as described in Pearson's Composition and Analysis of Foods, (Kirk & Sawyer, 1997).

The bulk density was determined according to the method described by Narayana and Rao (1984). Water and oil absorption capacities of the dehydrated milk were determined by the methods of Gbeddy (2001).

3.2. Colour determination

The colour of the dehydrated samples, based on the $L^*a^*b^*$ colour system, was determined with a Minolta Chroma Meter (Minolta CR 300 series). The Chroma meter was calibrated with a standard white tile ($L^* = 97.95$, $a^* = -0.12$, $b^* = +1.64$). The total colour difference $[\Delta E = (L^* - L)^2 + (a^* - a)^2 + (b^* - b)^2]^{1/2}$ was calculated from values for L^* - (lightness), a^* - (redness), b^* - (yellowness).

4. Microbiological analyses

4.1. Serial dilution

Ninety (90 ml) of 0.1% peptone water was added to 10 g of dried sample and homogenized in a stomacher for 60 s. Appropriate serial dilutions were prepared from the stock homogenate and used for the microbiological analyses.

4.2. Total plate count (TPC)

The total counts of the aerobic mesophilic bacteria were determined using the total plate count method, on Plate Count Agar (Oxoid Ltd., Basingstoke, Hampshire – England). The plates were

incubated at 35 °C for 48 ± 2h. The number of colonies were counted and recorded as colony forming units per gram of sample (cfu/g).

4.3. Yeasts and molds determination

Yeasts and mold population in the samples were determined by plating on Malt Extract Agar (pH 5.4 Oxoid Ltd., Basingstoke, Hampshire – England) and incubating at 25 °C for 5 days. The number of colonies developed were counted and recorded as colony forming units per gram of sample (cfu/g).

4.4. Coliforms determination (presumptive test)

Lauryl Tryptose Broth (pH 6.8 from Oxoid Ltd., Basingstoke, Hampshire – England) was used to determine the presence of coliforms. Fermentation tubes with inverted Durham tubes in them were used. The tubes were incubated at 35 °C for 48 ± 2h. The presence of gas trapped in the Durham tubes would indicate a positive test for coliforms.

4.5. Sensory evaluation

Dark milk chocolates were produced using a recipe for dark milk chocolate from Cocoa Processing Company, Tema, Ghana. The six dehydrated vegetable milks (enzyme treated and non-enzyme treated with three different ratios of peanuts to cowpeas) were used to replace dairy milk. A control chocolate was also produced using skimmed milk powder, to conform with commercial chocolate produced and marketed by the Cocoa Processing Company (CPC), Ghana. A panel of 30 untrained panelists evaluated the chocolates using a simple ranking test based on a 7 point hedonic scale with rankings of 1 (most preferred) to 7 (least preferred).

5. Experimental design and statistical analyses

The design of experiment was a full factorial design in which the factors and their levels were enzyme treatment (with and without enzyme), and peanut:cowpea ratio (three levels). Skim milk powder was used as control. Data was analysed using analyses of variance and where there were significant differences, Dunnett's multiple range tests was used to separate the means. The ranking data obtained from the sensory analyses were analysed using the Friedman test (Mielgaard, Civille, & Carr, 2006), in order to determine the vegetable milk with the most acceptable ratio of peanut and cowpeas when used as an ingredient in chocolate formulation.

6. Results and discussion

It was important for the dehydrated vegetable milk to have physical, chemical and functional characteristics comparable to skimmed milk powder (SMP). Consequently, malted rice extract was used as a source of amylase to breakdown starches in the vegetable milk and assure a vegetable milk consistency that would be close to that of dairy milk. Samples obtained from both the non-enzyme treated and enzyme treated milk were compared based on physical, chemical, functional and sensory characteristics to determine their suitability in milk chocolate processing.

6.1. Physical and chemical characteristics of the dehydrated peanut-cowpea milk

The proximate compositions of the dehydrated peanut-cowpea milk products as well as the control skimmed milk powder (SMP)

are presented in Table 1. The proximate composition of the skimmed milk powder was in line with reported values. The mean moisture contents of the dehydrated vegetable milk ranged from 2.34% to 3.66%, and were lower than the moisture content of SMP (control) which was 4.15. The quality standards of milk powder used for the processing of chocolate stipulates that the milk powder must have a maximum moisture content of 3.0% for full cream milk powder and 4.0% for skimmed milk powder (Awua, 2002).

The results indicate that the peanut–cowpea ratio as well as enzyme treatment had significant effects ($p \leq 0.05$) on product moisture content (Table 1).

In general the enzyme treated samples had higher moisture contents (probably due to increased reducing sugars) than the non-enzyme treated vegetable milk with similar ratios of peanut–cowpea. For the non-enzyme treated peanut–cowpea milk, increasing peanuts lowered the moisture content, probably due to the increasing fat content and lower level of sugars (predominantly from the cowpeas, Table 2).

The dehydrated vegetable milk had ash content of 2.10–2.80% (Table 2). The mean ash content of SMP (control) is much higher (8.11%), and compares well with the ash/mineral requirement of 8.20% for milk powder used in the processing of chocolate (Awua, 2002) Milk is a known source of minerals, particularly calcium (Devine, Prince, & Bell, 1996). There were significant ($p \leq 0.05$) differences in the total ash content among the vegetable milk samples. The differences were both from varying the peanut:cowpea ratios as well as from the amylase treatment. For the non-enzyme treated milk samples, as the peanut increased, the ash content decreased significantly, probably due to a dilution effect of increasing fat.

Table 1 shows that the mean fat contents of the dehydrated samples (21.42–40.92%) were much higher than the skimmed milk sample (1.03%) (control). Skimmed milk is milk from which much of the fat has been extracted. The results showed significant ($p \leq 0.05$) differences among the samples due both to the peanut–cowpea ratio and treatment of the vegetable milk with amylase enzyme. Peanuts have very high fat contents while cowpeas have very low fat contents. Consequently reducing the ratios of peanuts reduced the fat content of the dehydrated blends.

Fibre was significantly higher in the dehydrated vegetable milk samples as compared to the animal source control (Table 2). Dunnett's multiple range analyses showed that reducing peanut levels significantly increased the fibre content of the vegetable milk. This could be due to the higher carbohydrate content of the cowpea. (Deshpande & Damodaran, 1990; Kerr, Ward, McWatters, & Resurreccion, 2001) As expected, protein content was higher for the control (38.18%) SMP as compared to the dehydrated samples which ranged from 26.81% to 31.40% (Table 2). The differences among the samples were statistically significant. Because of the higher

protein content of peanuts as compared to cowpea (McWatters, Resurreccion, Beuchat, & Phillips, 1995), increasing amount of peanuts in the sample resulted in an increase in protein content. The carbohydrate content of the control (48.27%) was higher than that of the dehydrated vegetable milk samples which ranged from 26.81% to 31.40%. There were significant differences in all the samples. As the ratio of peanuts increased, the carbohydrate content decreased for both enzyme and non-enzyme treated vegetable milk samples. This can be attributed to the high carbohydrate content of cowpea, (Deshpande & Damodaran, 1990; Kerr et al., 2001) whilst peanuts have very low carbohydrate content.

6.2. Reducing sugars, pH and acidity of the dehydrated vegetable milk

The reducing sugars composition, pH and titratable acidity of the dehydrated peanut–cowpea milk samples are presented in Table 2. The control (SMP) had higher content of reducing sugars (36.70 g/100 g) than the dehydrated vegetable milk. Milk carbohydrate is exclusively in the form of lactose, a reducing sugar. Among the vegetable milk samples, the amylase treated samples had significantly higher reducing sugars (4.30–7.50 g/100 g) than the non-amylase treated samples (0.70–1.10 g/100 g). The increased levels of reducing sugars in the amylase treated samples is due to the breakdown of starch by the amylase enzyme into simpler (reducing) sugars. Similar results were reported by Tano-Debrah, Asiamah, Sakyi-Dawson, & Budu, 2005.

Titratable acidity which is indicative of the total acid concentration within a food was low in the dehydrated samples which ranged from 0.02 to 0.05 w/w lactic acid as compared with that of the control which was higher (0.16 w/w lactic acid). There were significant differences in the vegetable milk samples with the enzyme treated samples, having higher titratable acidity.

The pH for both the control and the dehydrated samples showed that they were all slightly acidic ranging from 6.33 to 6.97 for the vegetable milk samples, and 6.60 for the control SMP. Varying the peanut ratio significantly affected the pH, while enzyme treatment did not alter the pH significantly.

6.3. Mineral composition of the dehydrated peanut–cowpea milk

SMP (control) which is an animal source product was significantly higher in Phosphorus, Calcium, Zinc, Sodium and Potassium than the dehydrated peanut–cowpea milk samples. However, the peanut–cowpea milk samples were also significantly higher in Iron and Magnesium than the control. It was obvious that for the dehydrated samples, blending of peanuts and cowpea had an additive effect on some of the minerals, particularly phosphorus and iron (Table 3).

Table 1
Proximate composition of the dehydrated peanut–cowpea milk.

| Sample | Composition (%) | | | | | |
|--------------|----------------------------|--------------------------|---------------------------|--------------------------|---------------------------|--------------------|
| | Moisture | Ash | Fat | Fibre | Protein [*] | Carbohydrates |
| SMP(control) | 4.15 ± 0.03 | 8.11 ± 0.02 | 1.03 ± 0.90 | 0.26 ± 0.02 | 38.18 ± 0.01 | 48.27 |
| DP:CM(1:1) | ^c 3.26 ± 0.15 | ^d 2.51 ± 0.02 | ^a 21.42 ± 0.13 | ^d 2.58 ± 0.15 | ^b 27.97 ± 0.00 | ^e 42.26 |
| DP:CM(2:1) | ^{b,c} 3.14 ± 0.06 | ^b 2.21 ± 0.03 | ^d 33.56 ± 0.07 | ^a 1.20 ± 0.05 | ^c 29.06 ± 0.00 | ^c 30.83 |
| DP:CM(3:1) | ^a 2.34 ± 0.06 | ^a 2.10 ± 0.08 | ^f 40.92 ± 0.12 | ^b 1.40 ± 0.15 | ^d 30.14 ± 0.01 | ^a 23.10 |
| ETDP:CM(1:1) | ^c 3.22 ± 0.02 | ^e 2.64 ± 0.06 | ^b 23.37 ± 0.27 | ^a 1.12 ± 0.01 | ^a 26.81 ± 0.10 | ^f 42.84 |
| ETDP:CM(2:1) | ^d 3.66 ± 0.06 | ^f 2.80 ± 0.01 | ^c 26.23 ± 0.96 | ^c 2.02 ± 0.04 | ^c 30.58 ± 0.29 | ^d 34.71 |
| ETDP:CM(3:1) | ^b 3.03 ± 0.12 | ^c 2.29 ± 0.03 | ^e 34.96 ± 0.21 | ^b 1.47 ± 0.05 | ^f 31.40 ± 0.28 | ^b 26.85 |

Mean values ± standard deviations of three determinations.

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

^{*} Protein values are means of duplicate determinations. All others are triplicate determinations.

Table 2
Reducing sugars, titratable acidity and pH of the dehydrated peanut–cowpea milk.

| Sample | Reducing sugars (g/100 g) | Titratable acidity (w/w lactic acid) | pH |
|--------------|---------------------------|--------------------------------------|--------------------------|
| SMP(control) | 35.70 ± 0.42 | 0.16 ± 0.01 | 6.60 ± 0.00 |
| DP:CM(1:1) | ^a 1.10 ± 0.42 | ^a 0.02 ± 0.01 | ^c 6.97 ± 0.06 |
| DP:CM(2:1) | ^a 1.10 ± 0.14 | ^a 0.02 ± 0.01 | ^c 6.97 ± 0.06 |
| DP:CM(3:1) | ^a 0.70 ± 0.00 | ^b 0.03 ± 0.00 | ^a 6.33 ± 0.12 |
| ETDP:CM(1:1) | ^c 7.50 ± 0.14 | ^d 0.05 ± 0.01 | ^b 6.67 ± 0.06 |
| ETDP:CM(2:1) | ^b 4.40 ± 0.28 | ^{b,c} 0.04 ± 0.01 | ^b 6.73 ± 0.12 |
| ETDP:CM(3:1) | ^b 4.30 ± 0.42 | ^{c,d} 0.04 ± 0.00 | ^b 6.73 ± 0.06 |

Mean values ± standard deviations of three determinations.

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

6.4. Colour of the dehydrated peanut–cowpea milk

The samples were all generally creamy-white in colour but were significantly different from the control and from each other (Table 4). This is demonstrated in the L^* and b^* values of the chromameter values. L^* is a colour parameter that measures the extent of lightness, thus L^* when 0 would indicate black, and when 100 would indicate white; b^* value when positive signifies yellowish colour co-ordinate. As peanut ratio increased in the milk, the L^* decreased, indicating darkening of the milk both in the enzyme and non-enzyme treated samples. The enzyme treated samples had significantly lower L^* values than the non-enzyme treated samples. This difference in colour might be attributed to non-enzymatic (Maillard) browning reactions between the reducing sugars produced in the enzyme treated samples and amino acids within the samples. Table 4 also shows the colour variations (ΔE) from the white tile. There was a significantly higher colour variation for samples that were enzyme treated than those that were not enzyme treated. Within groups of vegetable milk (enzyme treated and non-enzyme treated), the total colour difference (ΔE) significantly ($p \leq 0.05$) increased with increasing peanut ratio.

6.5. Bulk density of the dehydrated peanut–cowpea milk

The bulk densities of the dehydrated peanut–cowpea milk products were generally lower than that of the skimmed milk powder (control). The results also indicated that increasing the peanut ratio in the samples, led to a decrease in bulk density, probably due to increasing oil content. Cowpea may contribute more to the bulk density due to its higher starch and minerals content. The amylase treated samples had significantly higher bulk densities.

Table 3
Mineral composition of the dehydrated peanut–cowpea milk.

| Sample | Mineral composition (mg/100 g) | | | | | | |
|--------------|--------------------------------|---------------------------|---------------------------|----------------------------|--------------------------|---------------|------------------|
| | Phosphorus | Calcium | Iron | Magnesium | Zinc | Sodium | Potassium |
| SMP(control) | 968.02 ± 3.22 | 734.39 ± 3.22 | 1.27 ± 0.67 | 90.50 ± 0.12 | 9.34 ± 0.06 | 620.87 ± 4.13 | 1,452.03 ± 59.56 |
| DP:CM(1:1) | ^b 189.23 ± 0.23 | ^d 23.91 ± 0.49 | ^a 6.78 ± 0.35 | ^d 141.40 ± 0.06 | ^e 5.54 ± 0.12 | 460.74 ± 5.24 | 651.04 ± 3.69 |
| DP:CM(2:1) | ^d 238.85 ± 0.20 | ^a 13.33 ± 0.31 | ^d 17.47 ± 0.38 | ^b 132.76 ± 0.31 | ^b 4.63 ± 0.06 | 460.09 ± 5.46 | 560.11 ± 3.95 |
| DP:CM(3:1) | ^c 221.29 ± 0.35 | ^f 28.08 ± 0.67 | ^c 25.63 ± 0.15 | ^c 136.48 ± 0.64 | ^c 4.89 ± 0.15 | 431.73 ± 4.78 | 562.25 ± 6.01 |
| ETP:CM(1:1) | ^c 243.45 ± 0.3 | ^e 19.30 ± 0.63 | ^b 8.78 ± 0.45 | ^b 133.29 ± 0.49 | ^a 3.89 ± 0.06 | 492.51 ± 5.09 | 764.13 ± 5.84 |
| ETP:CM(2:1) | ^f 270.95 ± 0.42 | ^e 25.17 ± 0.49 | ^a 7.03 ± 0.53 | ^a 116.30 ± 0.26 | ^f 5.79 ± 0.06 | 401.61 ± 4.26 | 682.73 ± 4.98 |
| ETDP:CM(3:1) | ^a 179.09 ± 0.31 | ^b 17.13 ± 0.71 | ^c 13.66 ± 0.42 | ^e 157.72 ± 0.63 | ^d 5.24 ± 0.06 | 460.92 ± 6.19 | 531.06 ± 4.69 |

Mean values ± standard deviations of three determinations.

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

Table 4
Colour indices of the dehydrated peanut–cowpea milk.

| Sample | L^* | a^* | b^* | ΔE |
|--------------|---------------------------|---------------------------|---------------------------|--------------------------|
| SMP(control) | 93.85 ± 0.20 | −4.09 ± 0.07 | 9.05 ± 0.19 | 8.69 ± 0.11 |
| DP:CM(1:1) | ^f 97.30 ± 0.28 | ^b 0.23 ± 0.01 | ^a −0.20 ± 0.10 | ^a 2.46 ± 0.13 |
| DP:CM(2:1) | ^d 93.51 ± 0.06 | ^c 0.61 ± 0.04 | ^b 0.45 ± 0.16 | ^c 4.58 ± 0.06 |
| DP:CM(3:1) | ^b 92.14 ± 0.03 | ^b 0.20 ± 0.04 | ^d 3.36 ± 0.06 | ^d 5.67 ± 0.04 |
| ETDP:CM(1:1) | ^e 94.07 ± 0.15 | ^a −0.03 ± 0.04 | ^b 2.52 ± 0.10 | ^b 3.61 ± 0.15 |
| ETDP:CM(2:1) | ^c 92.75 ± 0.04 | ^c 0.60 ± 0.02 | ^e 4.88 ± 0.15 | ^e 5.71 ± 0.08 |
| ETDP:CM(3:1) | ^a 88.50 ± 0.14 | ^d 1.06 ± 0.06 | ^c 2.76 ± 0.12 | ^e 9.29 ± 0.13 |

Mean values ± standard deviations of four determinations.

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

6.6. Oil absorption capacity (OAC) of the dehydrated peanut–cowpea milk

Both the enzyme treated and untreated samples showed increasing oil absorption capacity (OAC) as peanut ratio in the mixture was increased from 1:1 to 2:1 (Table 6). However, a decrease in OAC was observed as peanut ratio was further increased to 3:1. The enzyme treated samples generally showed lower OACs as compared to the non-enzyme treated samples. The dehydrated vegetable milk with peanut–cowpea ratio of 2:1, had the highest oil absorption capacity (OAC) of 0.98 g oil/g as compared to the enzyme hydrolyzed sample which had an OAC of 0.73 g oil/g. The oil absorption capacity of the dehydrated peanut–cowpea milk will

Table 5
Functional characteristics of dehydrated peanut–cowpea milk.

| Sample | Bulk density (g/cm ³) | Oil absorption capacity (g oil/g sample) | Water absorption capacity (g water/g sample) |
|--------------|-----------------------------------|--|--|
| SMP(control) | 0.76 ± 0.02 | 0.86 ± 0.03 | 0.31 ± 0.04 |
| DP:CM(1:1) | ^b 0.54 ± 0.01 | ^d 0.83 ± 0.03 | ^b 0.93 ± 0.01 |
| DP:CM(2:1) | ^a 0.52 ± 0.01 | ^f 0.98 ± 0.03 | ^b 0.96 ± 0.05 |
| DP:CM(3:1) | ^a 0.52 ± 0.00 | ^e 0.92 ± 0.06 | ^a 0.72 ± 0.01 |
| ETDP:CM(1:1) | ^e 0.67 ± 0.00 | ^b 0.63 ± 0.03 | ^b 1.01 ± 0.01 |
| ETDP:CM(2:1) | ^d 0.63 ± 0.00 | ^c 0.73 ± 0.03 | ^b 0.92 ± 0.10 |
| ETDP:CM(3:1) | ^c 0.59 ± 0.01 | ^a 0.58 ± 0.06 | ^a 0.75 ± 0.03 |

Mean values ± standard deviations of three determinations.

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

Table 6
Preference ranking of dark milk chocolate prepared with cowpea–peanut milk.

| Chocolate samples | Sum of ranks | Order of ranks |
|-------------------|----------------------|----------------|
| SMP(control) | ^a 84.0 | 1st |
| DP:CM(1:1) | ^b 117.0 | 4th |
| DP:CM(2:1) | ^{a,b} 111.0 | 2nd |
| DP:CM(3:1) | ^{a,b} 113.0 | 3rd |
| ETDP:CM(1:1) | ^c 168.0 | 7th |
| ETDP:CM(2:1) | ^b 121.0 | 5th |
| ETDP:CM(3:1) | ^b 126.0 | 6th |

Mean values having different superscript letters in columns are significantly different ($p < 0.05$).

SMP – skimmed milk powder.

DP:CM – dehydrated peanut–cowpea milk.

ETDP:CM – enzyme treated dehydrated peanut–cowpea milk.

have implications on its dispersability in the continuous (cocoa butter) phase in chocolate manufacture.

6.7. Water absorption capacity (WAC) of the dehydrated peanut–cowpea milk

The dehydrated samples had significantly higher WACs as compared to the control. Narayana and Rao (1982) attributed the increased water absorption capacity of heat processed flours to heat dissociation of the protein, gelatinization of carbohydrates in the flours and swelling of crude fibre. The gelatinization of starch in the peanut–cowpea blends probably reflected the higher WACs than the control. As the cowpea ratio decreased, starch content decreased and WAC dropped significantly (Table 5). Although the peanut–cowpea ratio affected the WAC significantly, the effects of enzyme treatment were not significant on WAC of the peanut:cowpea blends. The samples with the least WAC were the samples with the highest content of peanut, irrespective of enzyme treatment.

6.8. Microbiological quality of the dehydrated peanut–cowpea milk

The microbiological quality of the samples was within acceptable limits. A combination of the heating during the drum-drying process and the very low moisture content of the samples limited the growth of microorganisms. The total plate count (TPC) of the peanut–cowpea milk samples was between 5.0×10^2 and 2.5×10^3 colony forming units (CFU); no yeasts were present in any of the samples; molds ranged between 0 and 30 CFU; there were also no coliforms in any of the samples.

6.9. Sensory evaluation for acceptable ratio of peanut–cowpea milk in chocolates

The level of preference of chocolates made using the six vegetable milk samples as well as a control (skimmed milk powder) was obtained through a simple ranking test. The rank sums indicating the preference are shown in Table 6:

Friedman's rank test showed that milk chocolate made using dairy milk (control) was the most acceptable (having least rank sum). Chocolates made using non-enzyme treated vegetable milk were not significantly different in acceptability from the control. By the rank sums, even though there were no significant differences between them, vegetable milk DP:CM (2:1) and DP:CM (3:1) gave the most acceptable chocolates. This indicates that the samples with higher peanut ratios were more acceptable in the chocolate than those with lower amounts of peanuts. Chocolates made using any of the enzyme treated vegetable milk were not as acceptable to consumers. Chocolates made using enzyme treated

vegetable milk from cowpea–peanut at 1:1 ratio (i.e. ETDP:CM (1:1)) were the least preferred. This particular sample had the highest proportion of cowpeas and also had the highest amount of reducing sugars. Since all the enzyme treated samples produced the least liked chocolates, pre-treatment of the peanut–cowpea milk with the crude amylase may not be necessary if it is to be used in chocolate production. From the results of the sensory evaluation, sample DP:CM (2:1) was chosen to be used as a substitute for SMP in chocolate, since it ranked closest to the control (skim milk).

7. Conclusions

It is feasible to obtain acceptable dark milk chocolates by substituting dairy milk with dehydrated legume “milk”. Hydrolyzing the vegetable milk starch with amylases is not necessary since chocolates containing the non-hydrolyzed milk were more acceptable to the panelists. This is important because it reduces the processing steps for preparing the vegetable milk. The successful application and consumer acceptability of peanut–cowpea milk chocolates has the potential to increase the utilization of these crops and enhance their market value. If accepted by industry, the incorporation of vegetable milk will help lower chocolate costs.

Acknowledgements

This research was partly funded by Cocoa Processing Company Limited, Tema – Ghana. The assistance of Mr. Saakwa of the Ecological Research Laboratory of the University of Ghana, Legon, is also acknowledged. The Research was also partly funded by the USAID-funded Bean-Cowpea Collaborative Research Support Program (CRSP) project of the Department of Nutrition and Food Science, University of Ghana.

References

- Akinyele, I. O., & Abudu, I. A. (1990). Acceptability and nutrient content of milk substitutes from four cultivars of cowpeas (*Vigna unguiculata*). *Journal of Food Science*, 55, 701–707.
- AOAC (1990). *Official methods of analysis* (13th ed.). Washington DC, USA: Association of Official Analytical Chemists.
- Asiamah, K. (2005). Process optimization of cowpea–peanut milk. M.Phil. Thesis, Department of Nutrition and Food Science, University of Ghana.
- Awua, P. K. (2002). *The success story of cocoa processing & chocolate manufacture in Ghana*. Essex, Great Britain: David Jamieson & Associates Ltd., pp. 33–63, 65.
- Chandrasekhara, M. R., Ramanatham, G., Rama Rao, G., Bhatia, D. S., Swaminathan, M., Sreenivasan, et al. (1964). Infant food based on coconut protein, groundnut protein isolates and skim milk powder. I. – Preparation, chemical composition and shelf-life (2006). *Journal of the Science of Food and Agriculture*, 15(12), 839–841.
- Deshpande, S. S., & Damodaran, S. (1990). Food legumes: Chemistry and technology. In Y. Pomeranz (Ed.), *Advances in cereal science and technology* (Vol. X, pp. 147–241). St. Paul, MN: American Association of Cereal Chemists, Inc.
- Deshpande, R. P., Chinnan, M. S., & Phillips, R. D. (2008). Process development of a chocolate flavoured peanut–soy beverage. *International Journal of Food Science and Technology*, 43(5), 886–894 (9).
- Devine, A., Prince, R. L., & Bell, R. (1996). Nutritional effects of calcium supplementation by skim milk powder or calcium tablets on total nutrient intake in postmenopausal women. *American Journal of Clinical Nutrition*, 64, 731–737.
- Diarra, K., Nong, Z. G., & Jie, C. (2005). Peanut milk and peanut milk based products production: A review. *CRC Critical Reviews in Food Science and Nutrition*, 45, 405–423.
- Egan, H., Kirk, R. S., & Sawyer, R. (1981). *Pearson's chemical analysis of foods* (8th ed.). London: Churchill Livingstone.
- Gbeddy, D. V. (2001). Production of miso-like products using local grain legumes. M.Phil. Thesis, Department of Nutrition and Food Science, University of Ghana.
- Kerr, W. L., Ward, C. D. W., McWatters, K. H., & Resurreccion, A. V. A. (2001). Milling and particle size of cowpea flour and snack chip quality. *Food Research International*, 34, 39–45.
- Kirk, R. S., & Sawyer, R. (1997). *Pearson's Composition and Analysis of Foods* (9th ed.). Singapore: Longman Singapore Publishers. pp. 196–197.
- McWatters, K. H., Resurreccion, A. V. A., Beuchat, L. R., & Phillips, R. D. (1995). Use of peanut and cowpea in wheat-based products containing composite flours. *Plant Foods for Human Nutrition*, 47(1), 71–87.

- Mielgaard, M., Civille, G. V., & Carr, B. T. (2006). *Sensory evaluation techniques* (4th ed.). Berlin: CRC press. pp. 448.
- Mulando, T. M. M., & Resurreccion, A. V. A. (2006). Peanut Extract and Emulsifier Concentration affect Sensory and Physical Properties of Liquid Whitener. *Journal of Food Science*, 59(2), 344–349.
- Nadutey, Y. D. (1999). Process characteristics of yoghurt-like product from cowpea and groundnut milk. B.Sc. Project Report, Department of Nutrition and Food Science, University of Ghana.
- Narayana, K., & Rao, M. S. (1982). Functional properties of raw and heat processed winged bean (*Psophocarpus tetragonolobus*) flour. *Journal of Food Science*, 57, 1534–1538.
- Narayana, K., & Rao, M. S. N. (1984). Effect of partial proteolysis on the functional properties of winged bean (*Psophocarpus tetragonolobus*) flour. *Journal of Food Science*, 49, 944–947.
- Nelson, A. I., Steinberg, M. P., & Wei, L. S. (1976). Illinois process for preparation of soymilk. *Journal of Food Science*, 41, 57–61.
- Senayah, M. A. K. (1993). Production and evaluation of vegetable (imitation) milk from groundnuts & melon seeds (egushie). B.Sc. Project Report, Department of Nutrition and Food Science, University of Ghana.
- Smith, A. K., & Circle, S. J. (1972). *Soy beans: Chemistry and technology* (Vol. I). West Port, CT: AVI Publishing Company.
- Tano-Debrah, K., Asiamah, K., Sakyi-Dawson, E., & Budu, A. S. (2005). Effect of malt enzyme treatment on the nutritional and physicochemical characteristics of cowpea–peanut milk. In *Proceedings of the 1st international edible legume conference/IVth world cowpea congress* (pp. 1–5), Durban, South Africa, 17th–21st April, 2005.