Effect of some processing methods on the complementary and functional properties of millet-soybean flour blends

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Abstract: The results obtained for the formulated custard products showed evidence of significant (P < 0.05) interaction of the basic raw materials used for the production. The functional properties of the samples varied significantly (P < 0.05) between the samples with the least gelation ranging from 2.00%–4.10%; water absorption ranged from 1.43%–2.80% while the bulk density ranged from 0.06%–0.93%. The P-value for lack-of-fit 0.956 indicates that it was not significant, invariably, the model equation is fitted. It was therefore observed that the independent variables had positive effect on the samples including the interaction effect. The commercial product was observed to absorb more water than the developed samples. The least gelation capacity of the commercial and untreated samples was comparably higher against the treated samples. The anti-nutritional factors of phytate and Saponin contents of the samples ranged from 1.94% to 3.00% and 3.50% to 5.30%, respectively. The untreated samples had the highest contents of...
both the Saponin and phytate content. The increased contents of the anti-
nutritional factors could be attributed to the unprocessed nature of the sample.
Furthermore, there were positive correlations of the independent variables on the
products. Significant variations (P < 0.05) were also observed for the calcium con-
tents of the custard samples with the calcium content ranging from 2.67 to 10.60
ppm, while the phosphorous content ranged from 304.00 to 491.80 ppm. These
selected minerals have importance in the health of growing children. Calcium is
needed for strong bones and teeth, while the phosphorus is important for phos-
phorylation reactions in the body.

Subjects: Food Additives & Ingredients; Processing; Product Development

Keywords: Infant foods; fortification; gelation; nutrition; cereals

1. Introduction
The high use of nutrient-dense foodstuff such as legumes and cereals to prepare complementary
foods for children has been suggested by a number of researchers (Nnam, 2000). Cereals generally
serves as the major source of energy in diet but they are known to be relatively low in lysine and
tryptophan but fair in sulphur-containing amino acids, that is, methionine and cysteine (Okoh, 1998).
Conversely, legumes are relatively rich in protein (19%–26%) and fat (40%–46%) and
contain moderate quantities of lysine, tryptophan and threonine. This class of food can therefore
form a good supplement to cereals since they provide adequate amount of lysine for growth and
maintenance. Furthermore, attempts have been made on the use of different processing methods
to enhance the nutrient content of foods, whereby fermentation may be used to detoxify and
improve the nutrient availability in some food products. Fermentation may also be combined with
frying/drying as in garrification. These effects emphasize that an integrated approach that com-
bines a variety of the indigenous/traditional food processing and preparation practices, including
the addition of even a small amount of animal-source foods, is probably the best strategy to
improve the content and bioavailability of micronutrients in plant-based diets in resource-poor
settings (Gibson et al., 2010). The use of such a combination of strategies can almost completely
remove phytate. This is important because phytic acid is a potent inhibitor of iron absorption, even
at low concentrations (Hurrel, 2004). Sprouting releases vitamins and makes grains and seeds
more digestible.

The use of combined strategies could also be essential in food products whose intended use
was to increase the functional properties of such food products. The bulk density of a flour
material affects its packaging requirement, and it is influenced by the particle size and density
of flour (Adeleke & Odedeji, 2010). If there is a significant difference, it may indicate that the
blends have different bulk handling and packaging requirements (Shittu & Adedokun, 2010).
Swelling power is an indication of the water absorption index of flour granules during heating
(Adeleke & Odedeji, 2010) while low solubility values may indicate low degree of starch
degradation during the processing of the flour. Thus, malting and fermentation of carbohy-
drates-based raw material could substantially degrade starch and increase the solubility index.
Conversely, high solubility value indicates high extent of degradation and vice versa (Banu
et al., 2012). The effect of combined processing treatments increases water absorption capa-
city, which is an indication of the level of granular integrity that determines the weakness of
associative forces between the starch granules to allow for more molecular surfaces to be
available for binding with water molecules (Shittu & Adedokun, 2010). According to Banu et al.
(2012), the polar amino acid in protein and polysaccharide is responsible for varying water
absorptions. Hence, the observation on the water absorption capacity may be a reflection of
the protein and carbohydrate content either in the single-strength intermediate product or the
blends. Several studies have also shown that the use of different processing methods had
a positive effect on the thermal properties and nutrient densities of processed foods (Usman et al., 2016; Nnam, 2000; NACMD, 2003).

In Nigeria, a number of cereal-legume combinations has been formulated. However, some researchers had drawn conclusions that the double mixes are deficient in many micronutrients as rightly observed by Eka (1998). Germination, sprouting and fermentation processes of plant foods have been suggested as other ways of improving the digestibility, nutrient densities and bioavailability of micronutrients. Dietary diversification, supplementation, and fortification of locally available foods could also result in improved micronutrient intake by Nigerian infants during the weaning period (NNN, 2000; Nnam, 2000; NACMD, 2003).

Legumes contain anti-nutritional factors, which are known to exert deleterious effects in man and animals when ingested. These interfere with digestive processes and prevent efficient utilization of the legume proteins. These toxic factors may occur in all parts of the plant, but the seed is normally the most concentrated source. The levels of deleterious substances in tropical legumes vary with the species of plant, cultivar and postharvest treatments, such as drying, soaking, autoclaving and malting of the seed (Osagie, 1998). Most legume grains are highly toxic to animals.

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**Figure 1. Flow Chart for the Production of Millet Flour.**

- Millet
- Sorting/ Cleaning
- Steeping (24h)
- Germinating (48h)
- Drying (70°C, 10h)
- Fermentation (48h)
- Toasting (10min)
- Dehulling
- Milling
- Sieving

[Malted, fermented and toasted millet flour]

**Figure 2. Flow Chart for the Production of Soybean Flour.**

- Soybeans
- Sorting/ Cleaning
- Steeping (24h)
- Germinating (48h)
- Drying (70°C, 10h)
- Fermentation (48h)
- Toasting (10min)
- Dehulling
- Milling
- Sieving

[Malted, fermented and toasted Soybeans flour]
Table 1. Mixture Design for Processing of Complementary Food Blends

| Coded Samples | Millet (X₁) | Soybeans (X₂) |
|---------------|-------------|---------------|
| A             | 100         | 0             |
| B             | 25          | 75            |
| C             | 50          | 50            |
| D             | 75          | 25            |
| E             | 0           | 100           |
| UMS           | 75          | 25            |
| CMS           | N/A         | N/A           |

if fed without adequate processing. However, man has through experience either learnt to avoid some legumes, which produce ill-effects, or devised a means of eliminating the toxic components through some kind of processing.

2. Materials and methods

1.1. Purchase of raw material
Seeds of soybean (Glycine max) and millet (Pennisetumamericanum) were obtained from Cereal Research Institutes Umudike, Abia State and Cereal Research Institute, Badeggi, Niger State, respectively.

1.2. Sample preparation
The grains were cleaned, washed, rinsed first in distilled water and then in 5% (w/v) sodium chloride solution in order to disinfect them. The grains were germinated according to Balandran–Quintana et al. (1998) (with modifications). The cleaned grains were soaked separately in distilled water (1:3 w/v) for 24 h in a small plastic bucket with the water changed every 8 h. After soaking, the water was drained off and the grains were divided into different portions, spread on a nylon bag and covered with a moistened cotton cloth and left to germinate at room temperature (25 ± 2°C) for 48 h. After the germination period, the grains were dried in a hot air oven at 70°C for 10 h with occasional stirring to ensure even drying. The sprouts were removed by gently rubbing between hands followed by manual winnowing. The germinated grains were fermented according to the method described by Conibe (2007) with modifications. The grains were steeped in tap water (1:4 w/v) in plastic buckets, which were covered, and the water was changed after 24 h. After 48 h, the grains were blanched. Blanching was conducted according to the method described by Iombor et al. (2009). The fermented grains were rinsed in clean water, then blanched in a boiling pot at 100°C for 10 min (1:5 w/v).

The blanched grains were then drained, cooled to room temperature (25 ± 2), manually dehulled and rinsed to remove the seed coat. The rinsed seeds were then oven dried at 80°C for 10 h. The grains were roasted separately in an open pan with continuous stirring until brown colour was developed. This took about 10 min and was aimed to develop colour and improve the nutty flavor in pearl millet. Afterwards, it was milled and sieved. The flours obtained (Figure 1 and Figure 2) from these methods were packed into zip-lock bags, sealed and stored until needed for formulation and analysis.

1.3. Product Design
The processed samples were formulated using mixture design as shown in Table 1.

UMS = Untreated Millet and Soybeans flour
Table 2. Proximate composition of millet and soybean flour blends

| Samples MF:SF | Protein (%) | Fat (%) | Fibre (%) | Ash (%) | Moisture (%) | CHO (%) | Energy (Kcal) |
|---------------|-------------|---------|-----------|---------|--------------|---------|--------------|
| 100:0         | 12.30 ± 0.01| 1.50 ± 0.01| 0.04 ± 0.01| 6.50 ± 0.10| 9.50 ± 0.10| 70.20 ± 0.13| 339.54 ± 6.00|
| 25:75         | 23.60 ± 0.01| 9.00 ± 0.01| 0.27 ± 0.02| 4.33 ± 0.60| 6.00 ± 0.02| 57.00 ± 0.54| 402.00 ± 2.20|
| 50:50         | 21.20 ± 0.03| 5.50 ± 0.20| 0.03 ± 0.01| 7.50 ± 0.01| 5.50 ± 0.01| 60.24 ± 0.18| 374.80 ± 0.96|
| 75:25         | 18.60 ± 0.02| 5.50 ± 0.21| 0.02 ± 0.01| 6.50 ± 0.02| 7.00 ± 0.02| 62.40 ± 0.20| 373.83 ± 1.57|
| 0:100         | 33.70 ± 0.02| 14.00 ± 0.02| 0.05 ± 0.01| 11.50 ± 0.01| 14.80 ± 0.31| 25.90 ± 0.30| 363.07 ± 1.13|
| CSM           | 13.50 ± 0.02| 1.50 ± 0.02| 0.04 ± 0.01| 4.50 ± 0.02| 12.50 ± 0.02| 67.90 ± 0.05| 339.17 ± 0.08|
| UMS           | 15.50 ± 0.05| 10.70 ± 0.01| 0.05 ± 0.01| 6.40 ± 0.01| 6.50 ± 0.02| 61.00 ± 0.02| 400.63 ± 0.08|
| RDA           | <15 g/day | 30 g/day | NA | <3% | <5% | 90 g/day | 300 |
CMS = Commercial sample

1.4. Proximate composition of the flour blends
The moisture (Mc), crude protein (CPC), crude fat (CfF), ash (Ac) and crude fibre (CrFi) contents of the millet, and soyflour blends were determined using the standard methods (AOAC, 2010). Total carbohydrate was calculated by difference.

The method of AOAC (2010) was used for the determination of saponin (Sac) and phytates (Phe) in the samples.

1.5. Functional properties
The bulk density (BD) and water absorption capacity (WAC) were determined using the method described by Onwuka (2016) while the least gelation capacity was determined by the method of Sathe et al. (1982).

1.6. Mineral element composition
Atomic absorption Spectrophotometer (AAS) AA series 6800 series Shimazo Corp was used for determination of Calcium (Cac) and phosphorous (Pc). Two grams of sample was weighed into a crucible and incinerated at 600°C for 2 h. Theashed sample was transferred into 100 ml volumetric flask, and 100 ml of distilled water was added into it and readings were taken on the AAS.

1.7. Statistical analysis
The data obtained was be subjected to analysis of variance (ANOVA) and Duncan Multiple Range Test to separate the means. A probability of 5% will be used to establish statistical significance (Ihekoronye & Ngoddy, 1985). Furthermore, a Simplex Centroid Mixture Design from a Minitab software Version 17 was used for the design of the work which helped in establishing the effect of the different combinations on the properties of the samples.

3. Results and discussion

2.1. Effect of some processing methods on the proximate composition of samples
Table 2 shows the result of the proximate composition of the treated, untreated millet and soybeans flour samples as well as the commercial replicate. The protein of the untreated flour blends was 15.5% while the treated blends ranged from 12.3% to 33.7% while the commercial sample was 13.5% for protein. Malting, fermentation and toasting showed a significant (P < 0.05) influence on the protein levels of the flour blends except 100% millet flour which showed a decrease in protein content. The commercial sample was also shown to be lower in protein content. Similar increase in protein content was observed by Maryann (2015), while Nnam (2000) also reported an increase in protein content of various cereals and legumes during germination and fermentation. The increase in protein content due to germination can be as a result of the synthesis of enzymatic protein by germination seeds. Onuoha and Obizoba (2001) had also reported an increase in the protein content of lima beans after 48 h fermentation. However, Abdalla (1998) observed a non-significant (P < 0.05) reduction in the protein content of pearl millet. Protein increase could be attributed to germination process. The results obtained showed there was a significant difference (P< 0.05) in the protein content of the different blends. The highest protein content was observed in the 100% soybean flour which was significantly different (P< 0.05) from all the other samples. All the samples were significantly different (P< 0.05) from one another. The lowest value was obtained in 100% millet flour. The samples with more soybeans appeared to have higher protein content compared to those with higher millet in their blends. Only 25:75 millet:soybean flour blends met with the estimated average requirement (EAR). It could be observed that the estimated regression coefficient for protein showed that the independent variable had a negative effect (P< 0.05) on the protein content of the blends. However, the interaction had a positive significant effect on the protein content of the samples.
CPC = 13.55X1 + 32.38X2 −7.12X1X2

The R²-value 92.24% and R²-adjust value 90.94% implied that the model was fitted. The P-value for lack of fit 0.000 implies it is not statistically significant and that the model is significant. Meanwhile, the fat content of the treated samples varied from 1.5% to 14.0% but the commercial sample was 13.5% while the untreated sample had a fat content of 10.7%. There was a significant (P<0.05) decrease in fat content of the treated samples except 100% soybean flour which had the highest value. The decrease in the other formulated laboratory samples compared to the untreated sample could be as a result of the combined effect of malting, fermentation and toasting. Many researchers have attributed the decrease in fat content to the effect of malting (Maryann, 2015; Shah et al., 2011). Obizoba and Atti (1994) reported that fermentation process leads to reduction in fat content due to the utilization of fat as energy source by the fermenting organisms. Current results showed that there were significant differences in fat content in the different blends. The blends of 75:25, 50:50 millet:soybean complementary foods had no significant difference (p > 0.05) between each other but differed significantly from the other samples. The highest value was obtained in 100% soybean infant food and it differed significantly (P< 0.05) from all other samples. This could be as a result of the soybeans not being defatted and the blend contained only soybeans. The lowest value was obtained in 100% millet formulae and this could be as a result of non-addition of soybeans in the blend. The 100% millet formulation had the same fat content as the commercial sample (1.5%). None of the blends met with the estimated average requirement (EAR).

Fc = 2.14X1 + 13.62X2−6.52X1X2

The estimated regression coefficient for fat showed that the independent variables had a negative significant effect on the fat content of the samples. The R²-value 95.8% and R²-adjust 95.1% implied the fit can be used to explain the model. However, the P-value for lack of fit 0.000 implies that it is not statistically significant, which indicates that the model was significant.

**NB:**

*Values are means ±S. D (n = 3). Means with the same letter along a column showed no significant difference at (p > 0.05)*

2.2. CSM = Commercial sample (Positive Control). UMS = Untreated Millet and Soybeans (Negative Control)

The combined treatment of malting, fermentation and toasting did not affect the level of fiber in the flour blends. The values of all the samples ranged from 0.02% to 0.05%. It was also observed that there were no significant difference (P< 0.05) between the different sample blends. The 25:75 millet:soybean flour blends and 75:25 millet:soybean flour blends had the lowest fiber content which was lower than the untreated sample. Also, the 100% millet flour contains 0.04% fibre which differed significantly (P< 0.05) from the other samples except sample commercial sample and the sample with 100 substitute level. The fiber content was observed to have decreased, whereas Maryann (2015) had reported an increase in the fibre content of pearl millet flour. The decrease in the fibre content in samples with millet flour could not be unconnected with the processing methods, such as fermentation and malting treatments. During fermentation, most of the fibre must have been hydrolyzed by β - amylase enzymes.

CFC = 0.04X1 + 0.04X2−0.05X1 X2

The estimated regression coefficient for fibre shows that the independent variables had a negative non-significant effect on the fibre content of the samples. The R²-value of 17.31% and R²-adjust 3.53% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.000 implied that it is not statistically significant, which indicates that the model was significant.
There was an observable significant (P< 0.05) influence of the combined treatment of malting, fermentation and toasting processes on the ash content of the different blends. The untreated flour blends had an ash content of 6.4% while the treated samples values ranged from 4.33% to 11.5% and the commercial sample had an ash content of 4.5%. There was an increase in ash content amongst the treated samples except 25:75 millet:soybean flour blends, which were lower than the untreated sample. Obizoba and Atti (1994) reported that fermentation at room temperature for 36.48 h and 72 h increased the ash content of pearl millet. Similarly, Maryann (2015) reported that the combined treatment of malting, fermentation and toasting increased the ash content of pearl millet. Malleshi (1986) reported that malting at 25°C for 48 h increased the ash content of pearl millet. Meanwhile, current studies had shown that the blends at different compositions significantly (p < 0.05) influenced the level of ash content. Though 25:75 millet:soybean flour blends had lower ash content than the untreated sample, the remaining treated sample had higher ash content than the untreated samples. One hundred per cent millet flour had the highest ash content and was significantly different from all other samples. The lowest value was observed in 25:75 millet:soybean flour blends which significantly differed from all other samples. There was no significant difference between 100% millet flour and 75:25 millet:soybean flour blends, and they differed significantly from all other samples. There was no significant difference between the untreated sample and 100% millet flour.

\[ Ac = 9.27X_1 + 4.25X_2 + 0.1X_1X_2 \]

The estimated regression coefficient for ash shows that the independent variables had a positive effect on the ash content of the samples. The R²-value of 47.55% and R²-adjust 38.81% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.042 implied that it is not statistically significant which indicates the model was significant.

The moisture content in the untreated sample was 6.5% and in the treated samples, the values ranged from 5.5% to 14.8%. Observable significant (p < 0.05) increase in moisture content in some of the treated samples in the different blends were noticeable. The 100% soybean flour (14.8%) had the highest value and it was significantly different from all other samples. The 25:75 millet: soybean flour blends had the lowest value, and it was also significantly different from all other samples. All samples differed significantly from each other. The samples with the lower moisture content will be more shelf stable than those with higher moisture content.

\[ Mc = 12.99X_1 + 12.02X_2 - 24.49X_1X_2 \]

The estimated regression coefficient for moisture showed that the independent variables had a negative effect on the moisture content of the samples. Also, the interaction had a positive non-significant effect on the moisture content of the samples. The R²-value of 50.07% and R²-adjust

| Samples | Bulk density | Water Absorption | Least Gelation |
|---------|--------------|------------------|---------------|
| MF:SF   |              |                  |               |
| 100:0   | 0.90±0.02    | 1.50 ± 0.01      | 2.00±0.06     |
| 25:75   | 0.89±0.04    | 1.50 ± 0.01      | 2.10±0.13     |
| 50:50   | 0.80±0.01    | 1.50 ± 0.01      | 2.00±0.06     |
| 75:25   | 0.93±0.01    | 1.43 ± 0.04      | 2.10±0.21     |
| 0:100   | 0.06±0.01    | 1.70±0.01        | 2.10±0.02     |
| CMS     | 0.62±0.01    | 2.80±0.01        | 4.10±0.18     |
| UMS     | 0.60±0.01    | 1.06±0.10        | 4.00±0.11     |
41.75% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.212 implied that it is not statistically significant, which indicates that the model was significant.

The results of the functional properties are shown in Table 3. The bulk density of the untreated flour blends was 0.06 g/ml while those of the treated samples ranged from 0.66–0.93 g/ml and that of the commercial sample was 0.62 g/ml. Some researchers (Balandran—Quintana et al., 1998) have reported that malting decreased the bulk density of extruded whole pinto beans. However, Onimawo and Asugo (2004) reported that germination increased the bulk density of germinating pigeon peas while Akubor and Chukwu (1999), observed a decrease in bulk density in African oil beans when fermented. Fermentation was observed not to have a significant influence on the bulk density of flours. Current studies showed that the blending of the different compositions significantly (P<0.05) increased. The 75:25 millet:soybean flour blends have the highest value in the treated sample, and it differed significantly (P<0.05) from every other sample. The 100% soybean flour had the lowest value and differed significantly from the rest of the treated samples. 25:75, 50:50 millet:soybean flour blends had the same values. There was no significant difference between them. The 100% millet flour had similar values close to 25:75, 50:50 millet:soybean flour blends.

\[ B_{Dc} = 0.92X_1 + 0.86X_2 + 0.01X_1X_2 \]

The estimated regression coefficient for bulk density showed that the independent variables had a positive effect on the bulk density of the samples. Also, the interaction had a positive non-significant effect on the moisture content of the samples. The \( R^2 \)-value of 70.59% and \( R^2 \)-adjust 65.69% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.205 implied that it is not statistically significant, which indicates that the model was significant.

The untreated flour blends had comparable values with the commercial sample which were recorded as 4.1% and 4.0%, respectively. All treated samples had the same values that ranged from 2.0% to 2.1%. This showed that the combined treatment had a significant (P < 0.05) effect on the samples. The least gelation was observed to have reduced making the treated sample have more stable gels than the untreated and commercial samples. This could be attributed to analytical error. Onimawo and Asugo (2004) reported that germination caused an increase in the least gelation of samples.

\[ L_{GC} = 2.02X_1 + 2.08X_2 + 0.04X_1X_2 \]

The estimated regression coefficient for least gelation showed that the independent variables had a negative effect. Also, the interaction had a positive non-significant effect on the moisture content of the samples. The \( R^2 \)-value of 3.45% and \( R^2 \)-adjust 0.000% implied that the fit cannot be

| Table 4. Anti-nutritional content of millet and soybean flour blends |
|------------------------|-----------------|-----------------|
| **Samples**         | **Phytate (mg/100 g)** | **Saponin (mg/100 g)** |
| MF:SF               |                  |                  |
| 100:0              | 2.33±0.07       | 4.90±0.10       |
| 25:75              | 2.31±0.02       | 4.20±0.02       |
| 50:50              | 2.30±0.07       | 4.70±0.20       |
| 75:25              | 2.00±0.02       | 4.00±0.20       |
| 0:100              | 2.00±0.01       | 3.50±0.20       |
| CSM                | 1.94±0.02       | 4.46±0.01       |
| UMS                | 3.00±0.02       | 5.30±0.10       |
used to explain the model. Also, the P-value for lack of fit 0.956 implied that it is not statistically significant, which indicates that the model was significant.

**NB:**

*Values are means ±SD (n = 3). Means with the same letter along a column showed no significant difference at (P > 0.05)*

### 2.3. CSM = Commercial sample (Positive Control). UMS = Untreated Millet and Soybeans (Negative Control)

The water absorption capacities of the treated samples were compared to the untreated samples. The untreated sample had a value of 1.06% while the treated samples had values that ranged from 1.43% to 1.7%. The commercial sample had the highest water absorption. There a significant (P < 0.05) increase in the water absorption of treated samples. This could be attributed to malting as reported by Onimawo and Asugo (2004). The high water absorption could be attributed to either high protein content or more hydrophilic polysaccharides during the process of sprouting. Nonetheless, high water absorption is a factor that the flour could be of use in food systems, which need hydration to improve handling characteristics and to maintain freshness. The commercial sample had the highest value for water absorption and it differed significantly from every other sample. The 100% soybean four had the highest value of the treated samples and it differed significantly from all other samples. There was no significant difference among 100% millet flour, 25:75, 50:50, 75:25 millet:soybean flour blends but they differed significantly from all other samples. The untreated sample had the lowest value and it differed significantly from all other samples.

\[
WAC = 1.58X_1 + 1.69X_2 - 0.75X_1X_2
\]

The estimated regression coefficient for water absorption showed that the independent variables had a positive effect. Also, the interaction had a positive significant effect on the water absorption capacity of the samples. The \( R^2 \)-value of 84.43% and \( R^2 \)-adjust 84.17% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.002 implied that it is not statistically significant, which indicates that the model was significant.

The viscosity of the untreated sample and treated samples were greatly influenced by the combined treatment of malting, fermentation and toasting. From Figure 4.1, the untreated sample had a viscosity level of 37.4 Pa.s, while the treated samples had lower viscosity levels ranging from 26.31 to 26.32. There was a significant decrease in the viscosity of treated samples. This reduction can be as a result of the activities of amylase that breaks down starch into simpler sugar, thus reducing viscosity (Mensah et al., 1991) during fermentation. The reduction during malting maybe due to starch degradation caused by the action of beta – and alpha – amylase that developed during the malting process (Mosha & Svanberg, 1983). Mensah et al. (1991) observed a decrease in the viscosity of fermented maize. Manero et al. (1989) also reported The 75:25 millet:soybean flour blends had the lowest value of viscosity of treated samples which is almost comparable to that of 50:50 millet:soybean flour blends.

Table 4 showed that malting and fermentation processes significantly (P < 0.05) influenced the phytate content of the flour blends. The treated samples had a reduced phytate content ranging from 2.0% to 2.33% while the untreated sample had a value of 3.0 mg/100 g and the commercial sample had a low value of 1.94 mg/100 g. The decrease in the phytate level can be attributed to increased activity of the enzyme phytate during malting and fermentation (Watcharaparapaipoon et al., 2010).

Sutardi and Buckle (1985) also reported similar results for phytate during malting and fermentation of soybeans. There was an observed significant difference in the phytate level of the different blends. There was a significant (P< 0.05) between 50:50 millet:soybean flour blends and 100% soybean flour. There was no significant difference between 75:25 millet:soybean flour blends and 100% soybean flour.
Table 5. Some mineral content of millet and soybean flour blends

| Samples      | Calcium (ppm) | Phosphorus (mg/100 g) |
|--------------|---------------|-----------------------|
| MF:SF        |               |                       |
| 100:0        | 4.00 ± 0.40   | 491.76 ± 0.02         |
| 25:75        | 4.00 ± 0.20   | 464.94 ± 0.01         |
| 50:50        | 2.67±0.42     | 482.80 ± 0.02         |
| 75:25        | 8.00±0.20     | 304.00 ± 0.02         |
| 0:100        | 4.00 ± 0.20   | 491.80 ± 0.02         |
| CSM          | 8.00±0.40     | 473.90 ± 0.01         |
| UMS          | 10.60±0.20    | 360.50±0.02           |

Millet:soybean flour blends. The 100% millet flour, 25:75 millet:soybean flour blends and 100% soybean flour had lower values of 2.0.

\[ P_c = 2.22X_1 + 2.08X_2 + M0.29X_1X_2 \]

The estimated regression coefficient for phytate content showed that the independent variables had a positive effect. Also, the interaction had a positive non-significant effect on the phytate content of the samples. The \( R^2 \)-value of 14.04% and \( R^2 \)-adjust 0.000% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.000 implied that it is not statistically significant, which indicates that the model was significant.

**NB:**

Values are means ±S. D (n = 3). Means with the same letter along a column showed no significant difference at (P > 0.05)

2.4. **CSM = Commercial sample (Positive Control). UMS = Untreated Millet and Soybeans (Negative Control)**

Melting and fermentation also significantly (P < 0.05) influenced the saponin content as shown in Table 4. From the table above, the untreated sample had a value of 5.3 mg/100 g which decreased in the treated samples. The treated samples had values ranging from 3.5 mg/100 g to 4.9 mg/100 g and the commercial sample had a value of 4.46 mg/100 g. There was an observed significant difference in the saponin content (Sc) of the different blends. The 100% soybean flour had the highest value of saponin content of the treated samples while 100% millet flour had the highest value of saponin content. The untreated sample differed significantly from every other sample. 100% millet flour and 75:25 millet:soybean flour blends did not differ significantly from each other but differed significantly from all other samples. The 25:75 millet:soybean flour blends and 75:25 millet:soybean flour blends did not differ significantly from each other but differed significantly from all other samples. The commercial sample differs significantly from other samples.

\[ Sc = 4.67X_1 + 3.63X_2 + 0.91X_1X_2 \]

The estimated regression coefficient for saponin content showed that the independent variables had a positive effect. Also, the interaction had a positive significant effect which was by chance on the saponin content of the samples. The \( R^2 \)-value of 53.90% and \( R^2 \)-adjust 46.22% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.000 implied that it is not statistically significant, which indicates that the model was significant. Melting, fermentation and toasting processes significantly influence the mineral
content of the flour blends. The table above shows results of calcium and phosphorus content.

The calcium content (Cac) of the untreated flour blends was 10.6 ppm while the treated samples ranged from 2.67 ppm to 8.00 ppm and 8.0 ppm for the commercial sample as indicated in Table 5. There is an observed significant (P < 0.05) decrease on the calcium content of the different flour blends. There was no significant difference between 75:25 millet:soybean flour blends and the commercial sample which had the highest value of 8.00 ppm. The lowest value was obtained in 50:50 millet:soybean flour blends which had a value of 2.67 ppm and it was significantly different from the rest of the treated samples. One hundred per cent millet flour and 100% soybean flour had no significant difference but differed significantly from all other samples.

\[ \text{Cac} = 5.14X_1 + 3.54X_2 + 1.52X_1X_2 \]

The estimated regression coefficient for calcium content showed that the independent variables had a positive effect. Also, the interaction had a positive non-significant effect on the calcium content of the samples. The R²-value of 10.37% and R²-adjust 0.000% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.000 implied that it is not statistically significant, which indicates that the model was significant.

**NB:**

Values are means ±S. D (n = 3). Means with the same letter along a column showed no significant difference at (P > 0.05). CSM = Commercial sample (Positive Control). UMS = Untreated Millet and Soybeans (Negative Control)

### 2.5. Determination of Anti-nutrients

Malting and fermentation significantly (P < 0.05) influenced the phosphorus content (Pc) of the flour blends (Table 5). The untreated sample had values ranging from 304 mg/100 g to 491.8 mg/100 g. There was an observable significant increase in the treated samples based on the composition of the different flour blends. The 100% millet flour and 100% soybean flour had the highest value of 491.8 and there was no significant difference between them, but they differed significantly from 75:25 millet:soybean flour blends which had the lowest value of 304 mg/100 g.

\[ \text{Cpc} = 448.1X_1 + 512.5X_2 + 266X_1X_2 \]

The estimated regression coefficient for Phosphorus content showed that the independent variables had a negative effect. Also, the interaction had a positive non-significant effect on the calcium content of the samples. The R²-value of 24.75% and R²-adjust 12.21% implied that the fit cannot be used to explain the model. Also, the P-value for lack of fit 0.000 implied that it is not statistically significant, which indicates that the model was significant. Thus, it must be noted that the calcium content of the formulated infant formulae is independent of the processing variables.

**Conclusion**

The research work showed the effect of combined treatment on the chemical, functional and mineral content of complementary foods formulated from millet-soybean flour blends. The results, when subjected to Simplex Centroid Mixture Design, showed the interaction effects of the different mixture components on the properties of samples. It may be concluded that complementary food samples could be produced from maize-defatted soybean blends using combined processing methods. Consequently, it was established that the combined effect of malting and fermentation significantly (P < 0.05) decreased the anti-nutritional factors, improved the content of phosphorus, while the effect on the calcium content could not
be established. Furthermore, the bulk density and water absorption capacity were improved, while there was significant decrease in the least gelation capacity of the treated samples. Similarly, some of the proximate parameters were much higher than the recommended daily allowance for complementary foods, such as the protein content and energy values, while others were either within limit or below the daily requirements for infants, implying that the samples could be used by other group of the population, such as the young and aged. It was observed that the fat content of the complementary samples were far below the children's daily requirement which is a good requirement population requiring low-fat foods.

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