DEVELOPMENT, PHYSICO-CHEMICAL PROPERTIES AND PROXIMATE COMPOSITION OF MAIZE BASED - SOY MILK

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ABSTRACT

Background: Lately, developing countries have directed their research endeavours to development of foods with a better protein quality by mixing legumes with cereals such that products attain a balanced nutritional quality. **Objective:** To develop an acceptable plant milk which can replace cow's milk, with a high protein content notably a balanced amino acid composition, evaluating its consumer acceptance through sensory evaluation, carrying out physico-chemical analysis and determination of the nutrient composition of both the most accepted blend of maize based-soy milk, and that of the formulation with equal quantities of maize and soy milk. **Methodology:** Maize based-soy milk formulations were produced from blends of raw maize milk (white maize species) and soy milk (clear hylem species). The ratios of maize milk to soy milk in the different formulations were; MTQ (90%:10%), KZX (80%:20%), BFK (70%:30%), ERY (60%:40%), and ACD (50%:50%) respectively. **Results:** Sensory evaluation results indicated that BFK was the most accepted formulation. Results of proximate analysis for the most acceptable formulation (BFK) revealed crude protein content of 3.64%, moisture content of 82.24%, crude fat content of 3.68%, total ash of 4.21% and total carbohydrates 5.88%. The formulation ACD (50% maize:50% soy) contained 3.98% crude protein, 83.97% moisture content, 4.01% crude fat, 3.89% total ash and 4.36% total carbohydrates. Both formulations BFK and ACD contained no detectable dietary fibre. Total solids of between 8.86 and 7.72^{0} Brix were obtained with titratable acidity of 0.03 to 0.05% while all the formulations showed fairly acidic levels. Addition of soymilk raised the crude protein, crude fat and moisture content of maize milk. Acceptability of maize based-soy milk decreased upon addition of soymilk due to the beany flavor. **Conclusion:** Due to its low-cost and easily accessible raw materials, acceptance and/or consumption of maize based-soy milk will provide an alternative source of nutritionally balanced milk to lactose intolerant individuals, vegetarians and low-income families in the developing countries.

INTRODUCTION

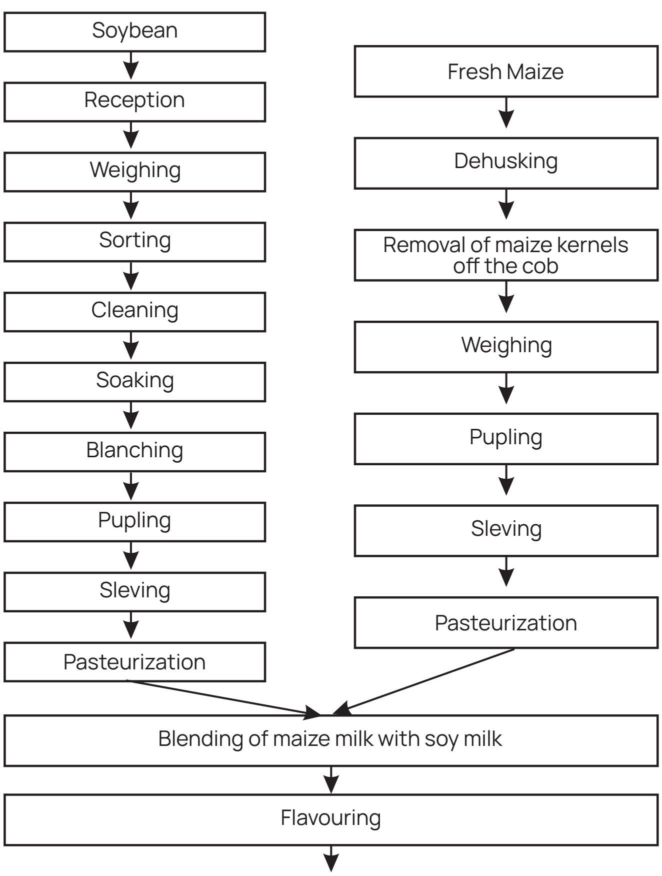
Maize (Zea mays) is a cereal crop widely cultivated by most households and every district in Uganda.[1] In developing countries, maize is processed in several ways and still remains a principal produce, due to its high energy density. Compared to other cereals, maize has a comparative agronomical advantage of its ability to be intercropped coupled with its high productivity. Maize is locally boiled and eaten, roasted or processed into flour. The grains can also be processed into maize milk, maize milk powder, maize yoghurt, cornflakes, among others.[2] Despite its considerable quantity of sulphur-containing amino acids, maize protein has low lysine. Though widely grown in almost all regions of Uganda throughout the year, most of the maize harvested undergoes postharvest losses, with very little reaching the fork, especially during bumper harvest seasons. Maize harvesting and storage in developing countries uses traditional methods and incur post-harvest losses of about 20-25%.[3] Maize is normally dried and processed into flour, with very little done on its fresh form. The fresh form is either just boiled or roasted and eaten, leaving much of it to perish in the fields since little value addition is done on it. Compared to the dried form, fresh maize has a higher nutritional quality, with its vitamin content at its peak. Research on fresh maize utilization and value addition as well as blending its fresh form with other crops is still scarce. Cereals and starchy roots top the list for food preferences of people in the developing world, with few legumes included. Unlike in western countries whose protein sources are animal-based, plant sources of proteins complement the starchy diets of majority of people in developing countries. This is mainly because animal sources of proteins are too costly for poor families to afford.[4] In recent years, different edible legume varieties with high protein content have been both identified and recommended to complement starchy diets globally. In this endeavour, soybeans (Glycine max) have been used for the enrichment of other foods and beverages for example traditional weaning foods, to improve their nutritional quality.[5] Throughout the years, infant food has been formulated from soy beans as a remedy to malnutrition and food intolerances linked to cow milk diets.[6] Use of soymilk as a beverage has gained traction globally and this is attributed to its health benefits such as reduced lactose, no cholesterol, delaying the on-set of heart diseases plus certain cancers.[7] Considering the many beneficial effects of soymilk to the body, research efforts aimed at increasing its acceptability need be hastened. According to the latest statistics available, [3] Nigeria has a large area under soybean production in Africa, followed by South Africa, Zimbabwe, Congo, Uganda, then Zambia. Cereals are deficient in the amino acid lysine which is compensated for by the surplus from legumes. [4] At the same time, legumes are deficient in sulphur-containing amino acids which are compensated for by the relative surplus from cereals.[8] Therefore, this research was aimed at developing a maize based-soy milk, of a well balancing amino acid composition, evaluating its nutrient content, and potential for acceptance, so as to enhance and boost nutrition security especially in poor families of low-developed countries, as well as addressing the issue of protein complementation and supplementation. Specific objectives of the study were to determine the i) acceptability of maize-based soy milk through sensory evaluation; ii) physico-chemical properties (Total Titratable Acidity, Total Soluble Solids and pH) of maize based-soy milk; iii) proximate composition of the most accepted milk blend and the formulation with equal amounts of maize and soy. Due to its low-cost and easily accessible raw materials, consumption of maize based-soy milk will help enhance utilization and food quality for poor households especially in under-developed countries. Its rich nutrient density implies that the product is ideal for everyone even for immune compromised individuals. Increased acceptance and consumption of maize based-soy milk will not only enhance the nutritional quality of the product through protein supplementation but will also reduce postharvest losses of fresh maize, provide an alternative source of nutritionally balanced milk, at a cheaper cost, addressing concerns of lactose intolerant individuals and vegetarians.

MATERIALS AND METHODS

Study design: Experimental stud
Setting: Department of Food Science and Nutrition, Faculty of Science, Islamic University in Uganda (IUIU). **Study duration:** 6 Months

Data collection procedure

Freshly harvested white maize (Zea mays) at a developmental stage characterised by juicy and milky grains (drying of the last tuft of hairs) was procured from farmers in Mbale central market, Uganda. Dried wholesome soy beans with a white or colourless hylem on the body of the bean were also bought. Metallic equipment used for processing of raw materials were made of stainless steel and included a grater, blender, batch pasteurizer, sieves, weighing balance, among others. Other items included muslin/cheese cloths, disposable cups, among others. Soy milk processing was done following an earlier reported method.This milk was pasteurized at 100 $^{\circ}$C for 30 minutes whereas the pasteurisation temperature-time combination for maize milk was 80^{0}C for 5 minutes. The unit operations involved in the development of maize-based soymilk are given in Figure 1 and different formulations of maize based-soymilk are given in Table1;



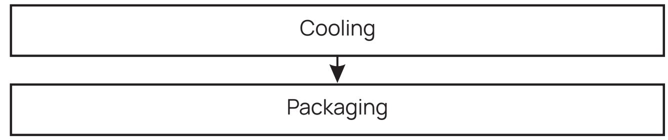


Figure 1: Flow diagram for preparation of maize based-soy milk.

Table 1: The different formulations of maize based-soymilk.

Formulation Code	Maize Milk (%)	Soymilk (%)
MTQ	90	10
KZX	80	20
BFK	70	30
ERY	60	40
ACD	50	50

Sensory evaluation Test

After preparation, sensory evaluation was conducted on the milk blends/formulations, employing the nine-point hedonic scale.[10] Fifty mL from each product formulation at room temperature was placed into separate plastic disposable cupsbearing 3-digit random letters. A total of 60 people randomly selected from IUIU students were used as panelists to assess the color, flavor, taste, consistency, plus overall acceptability of the milk samples. A sample from each formulation was served to each panelist. A sensory evaluation form bearing 3-digit random letters MTQ, KZX, BFK, ERY and ACD from different samples (Table 1) was given to each panelist to assess the corresponding sample product placed in a random order on the table in front of them. Each panelist was served with water to help rinse the mouth before and between successive sample evaluation. Panelists were requested to fill the sensory evaluation form, basing on the 9-point hedonicscale.[10]

Physico-chemical Tests

Total Soluble Solids (TSS) content was determined using the refractometer method. Two drops of the sample were put on a clean eye piece type refractometer glass, the brix was read and recorded in percentage. The Total Titratable Acidity (TTA) was determined according to a previously described procedure[11] using phenolphthalein indicator. pH was determined using a pH meter (ZZL 91023 ph600).

Proximate analysis

Proximate analysis for both the most accepted milk formulation and formulation ACD with equal quantities of soy milk and maize milk, was determined according to an International Official Method. Samples were analysed for crude protein, moisture content, crude fat, total ash, dietary fiber and total carbohydrate content.Assessment of the crude protein content was done using Kjeldahl method.To determine the moisture content, clean crucibles were dried in an oven for 30 minutes, cooled in a desiccator and weighed. The weight of the crucible was taken and 26 mL of the milk sample was weighed into a crucible. This was followed by drying the weighed milk sample (105 °C for 2 hours) in the oven and cooling in desiccators. The weight of the crucible plus the dried milk sample was recorded, after which the moisture content was calculated as follows;

$$\%\,Moisture = \frac{W2 - W3}{W2 - W1} \times 100$$

Where

W_1 = Initial weight of empty crucible (g)

W_2 = Weight of crucible + sample before drying (g)

W_3 = Final weight of crucible + sample after drying (g)

$W_2 - W_3$ = loss in weight (g)

The crude fat content was extracted with petroleum ether (40 °C) as a solvent using the semi-continuous method-Soxhlet apparatus (Soxhlet System HT, 1043 Extraction Unit) (Figure 2). To determine the crudefiber content, 15 mL of the sample was weighed and put into a beaker. Sulfuric acid solution (100 mL) was also added into the beaker. The sample was brought to boiling and refluxed for 1 hour.Upon completion of the digestion period (Figure 2), the beaker was removed from the heater, cooled and filtered with a cheese cloth. The residue was washed with boiling water to remove the acid and transferred to the beaker. The sample was dried at 100 °C, cooled into a desiccator and weighed. The sample was then burnt in an oven at 120 °C for 40 minutes, allowed to cool, and reweighed.

$$\%\text{ Ash content} = \frac{Weight\ of\ ash}{Weight\ of\ sample} \times 100$$

The total carbohydrate content was determined by difference method;

% carbohydrates =100 - (% fat + % moisture + % ash + % protein)

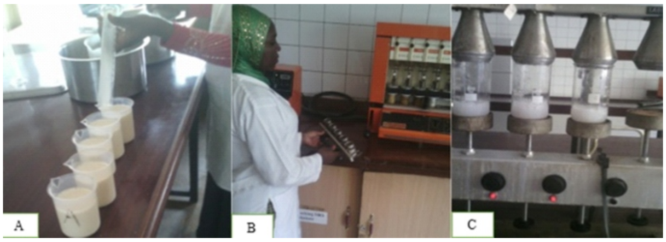


Figure 2: Formulating different blends of maize based-soy milk (A), loading samples into the Soxhlet machine for crude fat determination (B), and determination of dietary fibre content in the products (C).

Statistical analysis

Data in the present study was processed using the SAS software version 9.2. For sensory evaluation results, means were separated by the Duncan's multiple range test (DMRT) with 0.05 as the probability level, using one way analysis of variance (ANOVA) without sampling error.

RESULTS

Sensory evaluation

Mean score for the sensory evaluation results of maize based-soymilk from different formulations are given in Table 2;

Table 2: Sensory evaluation results for different formulations of maize-soy milk

Formulation	Color	Flavor	Taste	Consistency	Overall Acceptability
MTQ	3.99±0.94^{c}	7.97±1.02^{a}	6.52±1.00^{a}	1.44±0.93^{e}	6.23±0.79^{b}
KZX	5.91±1.15^{b}	7.74±1.00^{a}	6.44±1.25^{a}	2.93±1.43^{d}	7.51±1.06^{a}
BFK	7.30±0.95^{a}	7.68±0.91^{a}	6.39±1.08^{a}	7.00±0.80^{a}	7.60±0.67^{a}
ERY	6.26±1.13^{b}	5.97±0.98^{b}	3.71±0.92^{b}	5.63±1.11^{b}	4.13±0.90^{c}
ACD	7.08±0.24^{a}	4.39±0.56^{c}	2.80±0.41^{c}	4.26±0.13^{c}	2.97±0.35^{d}

Values in the table are Mean±Standard deviation. Values with the same superscript in the same column are not significantly different at $p \leq 0.05$ using the DMRT.

Physico-chemical analysis

Analysis results for the physico-chemical parameters in different formulations are presented in Table 3.

Table 3: Physico-chemical analysis results of the different formulations of maize-based soymilk.

Formulation	TTA(%)	TSS(oBrix)	pH
MTQ	0.04±0.02	8.86±0.03	8.86±0.03
KZX	0.03±0.01	7.72±0.03	7.72±0.03
BFK	0.05±0.01	7.93±0.01	7.93±0.01
ERY	0.04±0.03	8.64±0.02	8.64±0.02
ACD	0.03±0.02	8.71±0.01	8.71±0.01

Values in the table are Mean±Standard deviation

The least acceptability during sensory evaluation for formulation ACD can as well be attributed to its high pH (6.7).

Proximate analysis

Table 4: Nutrient composition of the milk blends BFK and ACD

Nutrient component (%)	BFK	ACD
Crude protein	3.64±0.05	3.98±0.06
Moisture content	82.24±0.03	83.97±0.02
Crude fat	3.68±0.02	4.01±0.03
Total ash	4.21±0.10	3.89±0.10
Crude dietary fiber	Too low to be detected	Too low to be detected
Total carbohydrates	5.88±0.20	4.36±0.21

Values in the table are Mean±Standard deviation

DISCUSSION

Color is a vital organoleptic attribute which enhances the product acceptability. From Table 2, no significant difference was observed in the color between formulations of KZX and ERY, and also between formulations BFK and ACD. The color of formulation BFK was the most preferred and formulation MTQ was the least preferred. The high preference of formulation BFK (70:30) may be attributed to the rich creamy color of soymilk, whose concentration in the formulation was appreciably enough to correlate with the creamy color of conventional cows' milk. Soymilk is a creamy emulsion, which not only looks like cow's milk but also has a similar spread on the tongue. [7] The color of formulations MTQ and KZX was disliked that much probably due to their higher maize milk content (90% and 80% respectively) compared to other formulations. Maize milk is almost snow-white in color, making it somewhat different from the color of conventional cows' milk, that panelists were familiar to. Flavor is a sensation which induces temperature receptors, smell, and taste senses once a substance has been put into the mouth.[12] Although the first response towards any food is elicited by its appearance, the decision to accept or reject that food mainly depends on its flavour.[13]Compounds responsible for flavor in fresh maize include methyl salicylate, ethyl maltol and ethyl decadienoate. [9] From the results, flavor did not show significant difference between formulations of MTQ, KZX and BFK, but there was significant difference in the flavor of formulations ERY and ACD. The flavor of formulation MTQ was the most preferred followed by KZX, BFK and then least for ACD. The high preference of the flavor in formulation MTQ may be attributed to the least quantity of soymilk (10%) and the reverse is true for the least preference of the flavor in formulation ACD (50% soymilk).Similar findings have been reported previously. [4] Soy milk contains a beany flavor, which imparts an objectionable flavor and taste. Taste is a sensory attribute which uses taste buds of the tongue to draw a difference between salty, sour, bitter and sweet qualities in dissolved substances.[14]Taste greatly determines the acceptability of a product.[15] The taste of formulations MTQ, KZX and BFK had no significant difference from each other, but differed significantly from formulations ERY and ACD. Preference of formulation MTQ was the highest followed by KZX, BFK, ERY and formulation ACD was the least preferred. The highest concentration of fresh maize milk in formulation MTQ (90% maize milk) can probably explain the reason for its high preference. Fresh maize contains a high concentration of reducing sugars, still at their peak, which fairly contributes to sweetness of maize milk. The above observation can also be attributed to the objectionable beany flavor of soymilk as noted by a considerable number of panelists. This also tallies well with reports of similar studies conducted elsewhere.[16]Consistency characterizes how a food settles on the tongue for example its thinness, wateriness, graininess, oiliness, among others. [12] Present results showed a significant difference in the consistency of each formulation. The consistency of formulation BFK was the most preferred followed by ERY, ACD, KZX and then least for MTQ. Soy milk is a creamy emulsion, which not only looks like cow's milk but also has a similar spread on the tongue. [7] This can probably explain why preference generally decreased with increase in maize milk addition of the different formulations. Maize milk is starchy hence imparts a thick consistency, quite different from the characteristic thin consistency of conventional cows' milk. This as well partly explains why preference generally increased with reduction in maize milk concentration. Formulation BFK (70% maize milk: 30% soy milk) was the most preferred. This can be attributed to the fact that the formulation contained a representative content of soymilk, unlike for example formulation ACD with 50% soymilk that could have made the consistency watery hence low water holding capacity, as noted by some panelists. Overall acceptability is based on multiple organoleptic quality parameters and indicates the cumulative perception and acceptance by the panelists. Results in Table 2showed no significant difference in the overall acceptability between formulations KZX and BFK. The overall acceptability was highest for formulation BFK followed by KZX, MTQ, ERYand then least for ACD. The high acceptability score for formulation BFK could be attributed to the substantial quantities of soymilk added to maize milk which could have contributed to better sensory attributes mainly color and consistency. Overall acceptability generally decreased with increase in the addition of soymilk. This may be because of the beany taste of soybean which is not acceptable to most people. [16] Sensory evaluation results revealed that generally, the increased addition of soymilk to maize milk significantly reduced the taste and flavor whereas the color was not greatly affected. The addition of soymilk to maize milk also reduced the overall acceptability ofmaize-based soy milk. This could probably be due to the beany flavor inherent in soymilk. The improvement in the consistency as soymilk concentration increased, corresponds with earlier reports. [7] The TTA for different formulations of maize based-soy milk ranged from 0.03 to 0.05%, with formulation BFK having the highest TTA of 0.05%.The observed TTA values for all the formulations were considerably higher than the TTA for pure soy milk (0.02%) reported in previous works. [7] Generally, the TTA decreased with an increase in soy milk concentration. Since TTA contributes to the flavor and pH of drinks, [12] this could explain why formulations ERY and ACD had very low scores for overall acceptability during sensory evaluation. In the same vein, this can as well explain why formulation BFK with the highest TTA had the highest overall acceptability during sensory evaluation. TSS of any fruit pulp increases with increase in the concentration of reducing sugars, as the fruit progressively ripens.[17] From the results in Table 3 above, there was no considerable variation in the different formulations of maize based-soy milk, as their TSS all lied in the range of 7.72 to 8.86^{0}Brix. Such results may be attributed to the fact that the same variety of raw materials and at the same stage of maturity, were used forprocessing the different blends/formulations of maize based-soy milk. Since TSS determines the taste/sweetness of any fruit pulp, [12] this might partly explain why formulation ACD (50% fresh maize) with the highest TSS also had the highest score for taste during sensory evaluation. The pH of the different formulations of maize-based soy milk ranged from 6.2-6.7.These pH values correlate with the recommended pH ranges of fresh cow's milk as per the Uganda National Bureau of Standards (US EAS 67:2006) and WHO/FAO.[18] High pH values above 7.2 not only favor microbial growthbut also lead to souring of milk and coagulation which in turn affects its acceptability.[19] The crude protein, moisture content and crude fat of maize-based soy milk (BFK) were considerably lower than that in an equal formulation of maizemilk and soy milk (ACD). However, the total ash and total carbohydrates in the latter (ACD) were lower than that in the former (BFK). In both formulations, the crude dietary fibre contents were too low to be detected. A similar finding was also observed in previous related studies[20] and seemingly suggests that these products are not reliable dietary fibersources. Nevertheless, theyare promising foods in satisfying the daily requirement for protein, mineral and fat. The reduction in protein and fat contents as maize milk concentration increasedin the present study, has also been cited in earlier works elsewhere. [4] Swelling of protein bodies during processing and hence causing physical destruction or shape loss, could be responsible for the observed decreases in protein content.[21] In the same vein, increase in fat, total carbohydrates, and proteins in formulation ACD compared to formulation BFK might be a result of the increased soymilk added to ACD,to produce an equal formulation of maize milk and soy milk (50% maizemilk:50% soymilk). The low-fat content in formulation BFK may lead to extended shelf life of the product through arresting rancidity. High fat content for example in formulation ACD induces off-flavor production during storage.[22] This also correlates with previous reports in related studies in which deterioration was higher during storage of soymilk-based products than in maize-based beverages.[23]There was an increase in ash content of formulation BFK compared to formulation ACD due to the mineral contents caused by the addition of maize as reported in previous related studies.[23]With a total ash content of 4.21%, the product can be said to contain sufficient amounts of minerals.Increased addition of maize in formulation BFK led to increase in carbohydrate content when compared with formulation ACD. Unfortunately, most previous works on soya bean carbohydrates are centered on sugars notablystarchyose, sucrose, and raffinose.[24] The reduction in moisture content of formulation BFK was due to an increase in starch content as maize milk addition increased, compared to formulation ACD with an equal concentration of maize and soy milk. Maize contains about 72% starch.[25]

The value obtained in the developed maize-based soymilk (BFK) is qualitative due to an improved protein content especially the balanced amino acids from plant sources. [4, 26] In the same vein, the most accepted formulation (BFK) addresses the issue of protein complementation and supplementation (70% maize milk: 30% soymilk).

CONCLUSION

From the present study, it is evident from that an acceptable plant milk can be produced from blends of maize milk and soy milk at various substitution levels. Maize based-soymilk gave a nutritious milk blend. Analysis results revealed that as the level of soy milk addition increased, the protein and fat contents increased as well. Although enriching maize milk with soy milk gave a nutritious beverage, overall acceptability decreased as the level of soy milk addition increased as a result of the beany flavorfrom soy milk. Maize based-soy milk could help improve access to cheap, good quality vegetable protein to not only vegetarians and lactose intolerant individuals, but to low-income earners as well.

RECOMMENDATIONS

Fortification of the developed maize based-soy milk with a fiber-rich crop is highly recommended since proximate analysis results revealed that the dietary fiber contents in both milk blends were too low to be detected.There is need for further research on the bioavailability of nutrients in the developed maize-based soymilk. Additionally, the microbiological safety and shelf-life of the developed maize-based soymilk need be addressed.

AUTHORS CONTRIBUTION

BK: Conceived the study concept Data collection and analysis Prepared the first draft of the manuscript. **AK:** Designed the study Sourced the required material and chemicals

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