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ORIGINAL PAPER

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OPTIMIZATION OF SOY MILK, MANGO NECTAR AND SUCROSE SOLUTION MIXES FOR A BETTER QUALITY SOY MILK-BASED BEVERAGE

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ABSTRACT

Background. Soy milk-based beverages play an important role as a healthy food alternative for human consumption. However, the 'beany' flavor and chalky mouth feel of soy milk often makes it unpalatable to consumers. The objective of the present study is to optimize a blend of soy milk, mango nectar and sucrose solution for the best quality soy milk-based beverage.

Materials and methods. This study was designed to develop a soy milk blended beverage, with mango nectar and sucrose solutions, with the best physicochemical and sensory properties. Fourteen combinations of formulations were determined by D-optimal mixture simplex lattice design, by using Design expert. The blended beverages were prepared by mixing the three basic ingredients with the range of 60−100% soy milk, 0–25% mango nectar and 0–15% sucrose solution. The prepared blended beverage was analyzed for selected physicochemical and sensory properties. The statistical significance of the terms in the regression equations were examined by Analysis of Variance (ANOVA) for each response and the significance test level was set at 5% ($p < 0.05$).

Results. The results showed that, as the proportion of mango nectar and sucrose solution increased, total color change, total soluble solid, gross energy, titratable acidity, and beta-carotene contents increased but with a decrease in moisture , ash, protein, ether extract, minerals and phytic acid contents was observed. Finally, numerical optimization determined that 81% soy milk, 16% Mango nectar and 3% sugar solution will give by a soy milk blended beverage with the best physicochemical and sensory properties, with a desirability of 0.564.

Conclusion. Blending soy milk with fruit juice such as mango is beneficial, as it improves sensory as well as selected nutritional parameters.

Keywords: beany flavor, blended beverage, mango nectar, sensory properties, soy milk

INTRODUCTION

According to the USDA, the Global Soybean Production in 2017 is expected to be 340.79 million metric tons, and it is expected that production will increase at the same rate continuous in the future (USDA, 2017). Soybean is a protein-rich food crop and is successfully used in baked foods such as bread, biscuits, cakes, chocolates and soy milk (Fabiyi, 2006). Soy milk is normally prepared by soaking soybeans in water and

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grinding. Researchers reported that soy milk is a rich source of plant proteins and is the best alternative to cow's milk, and is also a low-cost source of good quality energy for human consumption (Touba et al., 2013). Soy milk is reported to be rich in fat content (4.3%) compared to cow's milk (2.4%), minerals (Ca, Fe, Mg, P, K, Na) and different phyto-chemicals (flavonoids, inositol and isoflavones; Dewell et al., 2006). Furthermore, the increasing popularity of soy milk as a beverage worldwide is accredited to its health benefits. For instance, it is low in cholesterol and has the ability to reduce bone loss, menopausal symptoms and prevent and reduce the risk of heart disease, certain cancers, malnutrition and cardiovascular disease by reducing levels of low density lipoproteins (LDL) and triglycerides in the serum, reducing blood pressure and increasing the flexibility and permeability of blood vessels (Adebayo et al., 2009). Researchers have also reported the proven free radical scavenging activity of soy milk through isoflavones, which act as an effective tool to reduce oxidative degradation of DNA, preventing premature aging and the emergence of diseases such as Alzheimer's (Hsieh et al., 2009).

However, soy milk is often characterized as having an unbalanced ''beany'' flavor and chalky mouth feel, which are the major barriers to consumption by both children and adults. This is the major market problem experienced by the women soy milk producers association in Jimma, Ethiopia. The beany or nutty flavor is mainly due to lipoperoxidation of polyunsaturated fatty acids (PUFA) mediated by the lipoxygenase enzyme (Kale et al., 2011). The soy milk "beany" flavor and chalky mouth feel may be minimized by blending the soy milk with different fruit or vegetable juices and some spice and herb extracts, or other ingredients such as artificial flavors and sweeteners (Mojatahedi et al., 2013). Some reported blends are soy milk blended with ingredients such as chocolate and peanut (Deshpande et al., 2008), corn milk (Olusola et al., 2000; Omueti and Ajomale, 2005), cereals and grape must (Coda et al., 2012), coffee (Felberg et al., 2010), kunnu (Sowonola et al., 2005); orange juice (Kale et al., 2011); wild blueberry (Potter et al., 2007). Some of these blending studies have been successful in improving consumer attitude and acceptance regarding products made from soy beans (Zulueta et al., 2007). In this regard, in the present study attempts were made to improve the flavor and taste of the milk in Jimma town through the use of locally available flavors. Mango nectar improves the nutritional as well as therapeutic value of beverages, and also provides sweetness and masks the "beany" flavor of soy milk to some extent (Sakhale et al., 2012). In addition to mango nectar, sucrose solution can be added to gain multiple benefits in terms of masking the undesirable flavor, improving taste, serving as a source of energy and improving the rheological properties of the beverages (White, 2014). Therefore, the aim of this study was to optimize the ratio of soy milk, mango nectar and sucrose solution to improve the flavor of the beverages while enhancing the desired physicochemical properties and sensory acceptability.

MATERIALS AND METHODS

Experimental material

Soybeans of the "clark 63k" variety and "Tommy Atkins" mangos were collected from Jimma and Melkasa Agricultural Research Centers respectively. Commercial sugar was purchased from the local market to make sucrose solution.

Sample preparation

The soy milk was prepared by the Illinois method; the extraction of soy milk was carried out according to Onuorah at al. (2007), by soaking the soybeans overnight with a soybean:water ratio of 1:4 (w/v). After soaking, the water was drained and the beans were rinsed more than two times with clean water and blanched for 10 minutes at 100°C in 0.5% $NaHCO_3$ solution. Soy milk was extracted by blending the soaked soybeans using an electric blender for five minutes at high speed to extract the milk at room temperature (25°C). Fully ripened Tommy Atkins mangos were used to make mango nectar. The collected fruits were washed and peeled, the seeds were removed and the pulp was cut into thin slices and mixed with distilled water (mango:water ratio: 1:3 (w/v)) to prepare the nectar. The mixture was then blended for two minutes at high speed using a fruit blender (Liu et al., 2014). Sucrose solution was prepared using commercial table sugar and water (sugar:water ration: 1:5 (w/v)) and blended using a kitchen blender for five minutes at low speed (Doxastakis et al., 2002).

Preparation of soy milk-based beverage (SBB)

The soy milk-based beverages were blended according to different ratios, based on Table 1. Each beverage was blended using a blender for two minutes at high speed (Kale et al., 2011). Blended samples were poured into transparent glass bottles, sealed with crown caps, pasteurized for 30 minutes at 71 ±2°C and stored at 4°C in a refrigerator for further analysis (Kabiru et al., 2012).

Experimental design

The experimental design was formulated by Design--Expert® (version 6.02 Minneapolis MN, USA) software. D-optimal constrained mixture simplex lattice design was used to formulate the 14 compositions of the soy milk (SM), mango nectar (MN) and sucrose solution (SS) as indicated in Table 1. Upper and lower limits were decided by preliminary experiments conducted before the original research was initiated and

Table 1. Values and *p*-values of beverage changes in color, total soluble solids, proximate composition, titratable acidity, pH and beta-carotene

Treatments	SM %	MN %	SS %	ΔE	TSS °Brix	MC %	Ash %	Protein %	EE %	CHO %	GE kcal/100 g	TA %	pH	beta--carotene mg/100 g
T1	80	12	8	10.16	4.7	89.46	0.13	3.8	1.99	4.6	51.6	0.045	6.82	0.0002
T2	85	0	15	5.19	5.2	90	0.15	3.84	2.04	4.0	49.7	0.048	6.83	0.0009
T3	75	25	0	21.24	3.6	89.45	0.15	3.76	1.85	4.8	50.8	0.038	6.98	0.0007
T4	60	25	15	29.51	5.4	88.4	0.13	2.76	1.45	7.3	53.1	0.058	6.72	0.0012
T5	85	0	15	6.46	5.1	89.46	0.13	3.92	2.06	4.4	52.0	0.064	6.62	0.0012
T6	67	25	8	22.93	4.8	89.07	0.12	3.0	1.68	6.1	51.6	0.051	6.73	0.001
T7	75	25	0	20.94	3.5	89.36	0.14	3.64	1.92	5.0	51.6	0.054	6.76	0.0012
T8	100	0	0	0	2.3	90.63	0.15	5.44	2.37	1.4	48.7	0.051	6.85	0.0012
T9	86	6	8	8.42	4.5	90.03	0.12	4.28	2.16	3.4	50.1	0.061	6.68	0.0011
T10	73	12	15	11.36	5.3	89.2	0.17	3.2	1.82	5.7	51.8	0.038	6.97	0.0008
T11	100	0	0	0	2.4	90.95	0.16	5.36	2.32	1.2	47.2	0.042	6.89	0.0005
T12	92	0	8	3.07	4.3	90.52	0.13	4.72	2.25	2.4	48.5	0.051	6.78	0.001
T13	60	25	15	26.9	5.3	88.21	0.15	2.84	1.5	7.3	54.2	0.054	6.74	0.0013
T14	87	13	0	9.17	3.1	90.55	0.12	4.6	2.2	2.5	48.2	0.045	6.82	0.0003
Linear model				***	***	***	***	***	***	***	***	***	***	***
Quadratic model				ns	***	ns	ns	ns	**	ns	ns	ns	ns	***
Cubic model				ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Special cubic				*	ns	ns	ns	***	ns	ns	ns	**	ns	ns
Lack of fit				0.29	0.61	0.62	0.55	0.41	0.59	0.14	0.82	0.43	0.66	0.32
Adj. R^2				0.986	0.995	0.93	0.66	0.99	0.986	0.98	0.81	0.98	0.96	0.98

SM – soy milk, MN – mango nectar, SS – sucrose solution, TSS – total soluble solids, MC – moisture content, EE – ether extract and CHO – carbohydrate, GE – gross energy, TA – titratable acidity; ***$p < 0.001$, **$p < 0.05$, *$p < 0.05$ to 0.06 (marginally insignificant), ns – insignificant.

were limited to 60–100% SM; 0–25% MN and 0–15% SS. Preliminary study results indicated that a MN proportion of more than 25% results in coagulation of the beverage.

Data collected

The following selective physico-chemical properties were determined for the SBB.

Determination of total color change (∆E)

The total color change of each sample was measured using a color chromometer (Model of Accu-probe HH06M, U.S.A.) in daylight. Color measurement was recorded using Hunter L*, a* and b* scale (Hunter Associates Laboratory, 1996).

pH and titratable acidity (TA)

The pH of the SBB was determined using a digital pH meter according to AOAC (2010) official method 981.12. The pH meter was standardized (calibrated) using pH 4 and 7 buffer solution before being used to determine the pH of the sample. Titratable acidity content was determined by titration using standardized 0.1N sodium hydroxide solution and 1% phenolphthalein solution as indicator to determine end point of titration until light pink color appeared and persisted for 30 s (Akhtar et al., 2010).

Determination of TSS

Total soluble solids (TSS) of each sample was determined by hand held refractometer (Model, DR 201-95, Germany; AOAC, 2010).

Proximate composition

To determine the proximate composition, the moisture content was determined by hot air oven method, ash content was determined by dry ashing technique, protein concentration was determined by Kjeldhal and ether extract was determined by Soxhel extraction methods, as stated in official AOAC (2010) method numbers: 925.09, 923.03, 979.09, 45.01 respectively. Carbohydrate content was determined by difference method, as reported by Onyeike et al. (1995). Gross energy value was also determined by the method of Osborne and Voogt (1978).

Beta-carotene (β) content

Two grams of sample were mixed with one gram of $CaCl_2{\cdot}2H_2O$ and 50 ml extraction solvent (50% hexane, 25% acetone, and 25% ethanol). The mixture was shaken at five minute intervals for 30 min, while maintaining the temperature at 4 ±1°C in a refrigerator. 15 ml of deionized water was added and the resulting mixture was again shaken at five minute intervals for an additional 15 min at same temperature. The organic phase (beta-carotenoid) was separated using a separation funnel and filtered. The extraction procedure was carried out under subdued light to prevent degradation of the carotenoids. Beta-carotene content was determined using double beam UV-Vis spectrophotometer (T80 UV/VIS, UK) according to Sadler et al. (1990) by using 450 nm wavelength. Beta-carotene of the samples was estimated from a standard curve ($R^2 = 0.996$) of beta-carotene standard product of Sigma Aldrich.

Phytic acid content

Phytic acid analysis was carried out by spectroscopic method, as specified by Vaintraub and Lapteva (1988). About 0.06 gram of dried sample was extracted with 10 ml of 0.2N HCl for one hour at an ambient temperature and centrifuged at 3000 rpm for 30 min, and a clear supernatant sample was collected. The 3 ml of clear sample solution was mixed with 2 ml of wade reagent (0.03% solution of $FeCl_3{\cdot}6H_2O$ containing 0.3% sulfosalicylic acid in deionized water). The absorption of the mixture was measured at 500 nm using a double beam UV-Visible spectrophotometer. Phytic acid was calculated from curve ($R^2 = 0.996$) of standard phytic acid solution.

Mineral (Ca, Fe and K) analysis

Ca and Fe contents were measured by Atomic Absorption Spectrophotometer (AAS) according to the method of Hernández et al. (2005). The known weight of ash was treated with 5 ml of 6 N HCl and heated on a hot plate to dry it completely, and 15 ml of 3 N HCl was added. The crucible was heated on the hot plate until the solution boiled. It was then cooled and filtered and again 10 ml of 3N HCl was added to the crucible and heated until the solution boiled. Finally, the cooled sample was filtered through fine filter paper to 50 ml standard flask and distilled water was poured into the flask to the calibration mark. Using AAS, a calibration curve was prepared by plotting the absorption or emission values against the metal concentration in mg/100 g. The sample and standard were atomized using reducing acetylene with air gas for Ca and Fe as a source of energy for atomization (AACC, 2000). For Ca and Fe, content determination absorbance was measured at 422.7 and 248.4 nm respectively.

Potassium was determined by digital Flame Photometric method (Awonorin and Udeozor, 2014). 0.2 g of sample was poured into a 250 ml conical flask, 20 ml of nitric acid was added, and the resulting mixture was then boiled gently using a hot plate for 10 minutes and cooled to room temperature. The solution of each sample was filtered using filter paper into a 100 ml volumetric flask, and the volume was brought to 100 ml with deionized water. A control was prepared with the same procedure, without the addition of the sample. Standard K solutions were prepared separately.

Sensory analysis

Sensory evaluation was carried out based on the sensory parameters of color, flavor, taste, mouthfeel and overall acceptability on 5-point hedonic scale, varying from 5 – like very much, 4 – somewhat like, 3 – neither like nor dislike, 2 – somewhat dislike to 1 – dislike very much, according to the method of Kolapo and Oladimeji (2008). 50 untrained panelists were randomly selected from department staff, students and other people for the analysis. Before conducting the analysis, clear instructions were given to all the panelists and necessary measures were taken to remove various errors (Linda et al., 1991).

Data analysis

The statistical significance of the terms in the regression equations was examined by Analysis of Variance (ANOVA) for each response, and the significance test level was set at 5% ($p < 0.05$). Minitab statistical software (version 16) was used for data analysis and for response optimization (best treatment combination) of the result. The response optimizer analyses were conducted by setting minimum and maximum parameters value as per the importance of the parameters to achieve the intended goal (e.g. minimum value for phytic acid and maximum value for protein in the study range). In this paper, only parameters which showed significant difference in one of their interaction terms are indicated in the tables (Montgomery, 2013).

RESULTS AND DISCUSSION

Change in color and TSS of SBB

Response values for physico-chemical parameters are indicated in Tables 1 and 2. In all parameters, the linear model (effect of mixing the components) found to be highly significant ($p < 0.001$) was the mixture of components. However, in most cases, two- or three-way interactions were only observed for a few response variables.

Color is one of the most important criteria in influencing the decision to purchase. As indicated in Table 1, the total color change of beverages increase with an increase in proportion of MN than SS or SM. The overall total color change values vary from zero or no change (compared to the 100% SM control) to 29.51 for a beverage made from 60% SM, 25% MN and 15% SS. This modification could make a positive impact on consumers of the milk, with the assumption that the beverage has a different taste and flavor compared to pure SM. Unlike the three-way interaction of the mixture of components on the color value of SBBs, TSS value was significantly affected by the two-way interaction of SM with SS and MN with SS, in a quadratic model.

The effect of SS on TSS values of the beverages was also clear, as demonstrated by the increase in TSS value for higher SS concentrations. The values ranged from 2.3 to 5.4°Brix (Table 1), and a beverage with a high portion of MN and SS (60% SM, 25% MN and 15% SS) resulted in the highest TSS, while 100% SM had the lowest value. A similar result was also reported by Ribeiro et al. (2014), who indicated that an increase in the level of sugar content results in an increase in the TSS of beverages. Kale et al. (2011) also showed that the TSS content of soy milk-based orange juice beverage increased from 5 to 20.2°Brix as the soy milk ratio decreased from 90 to 10%. The modification of the TSS value of SBB with the addition of high TSS sources could modify the unwanted flavor of pure SM and improve the taste.

Table 2. Concentration and *p*-values of minerals (Ca, Fe, K) and phytic acid contents of SBB

Treatments	SM %	MN %	SS %	Ca mg/100 g	Fe mg/100 g	K mg/100 g	Phytic acid mg/100 g
T1	80	12	8	187.8	1.41	1 144.7	2.6
T2	85	0	15	204.8	1.43	1 016.1	2.8
T3	75	25	0	185.2	1.24	1 398.6	1.9
T4	60	25	15	163.1	1.03	970.2	1.1
T5	85	0	15	199.3	1.45	1 026.1	2.6
T6	67	25	8	168.2	1.18	1 112.1	1.4
T7	75	25	0	180.4	1.23	1 381.6	1.8
T8	100	0	0	242.7	1.84	1 640.4	3.3
T9	86	6	8	210.1	1.61	1 137.3	2.8
T10	73	12	15	175.1	1.2	1 005.0	1.8
T11	100	0	0	241.6	1.79	1 612.9	3.4
T12	92	0	8	231.0	1.74	1 184.9	2.9
T13	60	25	15	154.8	0.97	959.5	1.0
T14	87	13	0	223.6	1.64	1 480.9	2.9
Linear model				***	***	***	***
Quadratic model				ns	ns	ns	ns
Special cubic				*	*	*	*
Lack of fit				0.21	0.21	0.16	0.13
Adj. R^2				0.97	0.98	0.99	0.98

SM – soy milk, MN – mango nectar, SS – sucrose solution; ***highly significant, *significant, ns – non-significant.

Change in proximate composition

Moisture, ash, carbohydrate and gross energy values were only significantly affected in linear model terms due to the effects of mixing components. However, the components showed no significant interaction effects ($p > 0.05$) to modify these response variables. Moisture content varied from 88.21 to 90.95% which varied with the addition of the various components. Only soy milk (100%) had the highest value of 90.95%; this result is also in agreement with various works by different researchers (Ikya et al., 2013; Ribeiro et al., 2014).

The ash content of the beverage mixes ranged from 0.12–0.17%. This low value might be associated with the high moisture content of the beverage mixes, and adding beverage components in small proportions did not significantly affect the total ash content, since SM is rich in ash (Gesinde et al., 2008; Onuorah et al., 2007; Ribeiro et al., 2014). Drunkler et al. (2012) and Okoye et al. (2008) also indicated that the ash content of a beverage prepared from soy extract and cassava starch decreased from 0.48 to 0.37 and 0.17% respectively as the amount of soy extract decreased from 8 to 6 and 4 %.The protein content of SBB samples showed significant differences ($p < 0.05$) in two-way interaction, which is modeled in quadratic terms (Table 1). This value varied from 2.75 to 5.44%. Protein contents of the beverage were highly significant ($P < 0.01$) and varied in a linear fashion as the proportion of ingredients was modified. As expected, protein content increased with an increase in SM% and decreased with an increase in proportions of MN and SS. This trend might be correlated with the relatively high protein in SM (Ono et al., 1991). The protein component in soy milk has been reported to be high in comparison to mango (0.44–0.58%; Naz et al., 2014), and protein content would be zero in SS. This result is also in agreement with Sakhale et al. (2012) and Ikya et al. (2013), and indicated a decrease in protein content (4.04 to 2.75%) as soy milk percentage decreased (80–50%). This might be one of the limitations of this study into masking the beany flavor by adding additional components. The beverage samples also showed significant differences ($p < 0.05$) in terms of ether extract (EE) composition. Their value varies from 1.45 to 2.37% (Table 1). Like protein, EE increased with an increase in the proportion of SM and the highest value was observed in SM without any additives, but the lowest value was found for a beverage made from a mix of 60% SM, 25% MN and 15% SS, which implies that EE decreased with an increase in the proportion of MN and SS. Other studies have shown that a reduction in EE content occurs when SM is blended with other low fat/oil beverages, due to dilution (Augustine et al., 2013; Gatade et al., 2009; Onuorah et al., 2007). Salim et al. (2007), Sakhale et al. (2012) indicated that EE content increased from 0.62 to 0.81% as the proportion of SM increased from 50% to 80%.

The mixture components showed linear or cumulative significant effects on carbohydrate and gross energy (GE) values such as moisture and ash content. With the linear effect with the addition of MN and SS on SM, the carbohydrate content increased from 1.214 (100% SM) to 7.31 (60% SM, 25% MN and 15% SS). The same trend was followed for gross energy content (GE), which varied from 47.2 to 54.2 kcal/100 g, corresponding to the proportions indicated for carbohydrate. The energy content of this beverage is comparable with the results of Awonorin and Udeozor (2014) who reported that SBB gross energy values increased positively as carbohydrate content increased.

Titratable acidity and pH values along the TSS are important parameters to determine taste, flavor and overall acceptability of the beverage. Titratable acidity was significantly affected by the combination of components, in both two- and three-way interactions of components and modeled in quadratic terms. The three-way interaction among mixture components (SM*MN*SS) significantly altered the TA values, in the range of 0.038 to 0.064%. The highest TA value was recorded from the SBB with the highest proportion of MN (25%) and SS (15%), but it is believed that the change in TA value was mainly associated with MN. This result is in line with other reports about the high TA content of fruit juices used as beverage components (Kale et al., 2011; Peter et al., 2007; Rozina, 2012). This is an important modification to mask the undesired flavor of SM by imparting organic acid flavors from MN.

However, values of TA and pH varied among the different mixtures from 0.038% to 0.064% and 6.62 to 6.98 respectively. The highest TA value was found, as expected, for the highest proportion of MN (25%) with 15% sucrose and the lowest for 100% SM. When pH values were examined, in general, an increase in pH was observed with a decline in TA (Ribeiro et al., 2014). However, the results of preliminary work showed that (data not indicated) an increase in MN concentration beyond 25% results in coagulation of the beverage within 12 hours of storage, either in a refrigerator (4°C) or at room temperature. But for the studied range, the masking of the undesired flavor of SM can be achieved without causing a significant change to the TA and pH of the beverage.

Change in beta-carotene content

Beta-carotene is one of the carotenoid compounds, and a precursor to synthesis of vitamin A in our body. In the studied mixtures, the value varied from 2×10^{-4} to 1.27×10^{-3} mg/100 ml which corresponds with a beverage made from 85% SM and 20% SS with no addition of MN and 75% SM and 25% MN without SS respectively (Table 1). The ANOVA result also showed that there were significant ($P \leq 0.05$) interactions between SM*MN as well as MN*SS. This indicates the importance of adding MN to enhance the beta-carotene level of SM. The intense yellow-orange color of mango fruit pulp is a good source of beta-carotene (Singh et al., 2013). The result of this study is also in agreement with Madukwe and Eme (2012). They indicated that soy milk blended with carrot powder had higher beta-carotene content than plain soy milk. Omueti and Ajomale (2005) also indicated that yellow type soy-corn milk cream had higher levels of total carotenoid than plain soy milk. Therefore, adding MN to SM, as well as affecting flavor and taste, also enhances the beta-carotene value of the beverage to fight against vitamin A deficiency.

Effects on minerals (Ca, Fe and K) and phytic acid content

Minerals and phytic acid contents of the beverage mixes were determined to investigate the positive or negative effects of MN and SS on the beverages. Table 2 shows the actual value of selected mineral components and the phytic acid content of beverages in different mix proportions. Interactions between mixture components showed a significant effect ($p < 0.05$), which means that, with an increase in the amounts of MN and SS, Ca, Fe and K value are reduced. As indicated in different works, SM is rich in Fe, Ca and K compared to the other mixture components (Ezekiel and Fapohunda, 2012). Therefore, the reduction in these minerals might be associated with the dilution effects of an increase in proportions of MN and SS. However, compared to other beverages, due to the high percentage of SM in the mixtures the reduction in these mineral contents would not reduce the intake of these minerals to a level below the RDA. Rather, it has an indirect positive effect on enhancing the consumption of these minerals through enhanced flavor and taste of SM. A change in the concentration of minerals (Ca, Fe and K) results from a variation in the amounts of MN and SS.

Phytic acid is one of the known anti-nutrient compounds in SM, which contributes to binding Fe, Zn and Ca and impairs their absorption in the intestine. Reducing its concentration, either by using preprocessing treatments or through mixing SM with other components, increases the absorption of minerals. Phytic acid naturally occurs in most soybean products, in concentrations ranging from 1–3% (Esteves et al., 2010). But in this study the phytic acid content of SBBs varied from 1 to 3.31 mg/100 ml beverage. The highest was found in SM (100%) without the addition of MN and SS (Table 2), which is lower than in other reported studies (Jiang et al., 2013). The phytic acid contents of the beverages decreased with an increase in MN and SS and the lowest values were observed for 25% MN and 15% SS. This is an additional advantage of making SBB beverage mixes – reducing the mineral binding effects of phytic acid and enhancing bioavailability.

Changes in sensory properties

These days, the primary consideration of consumers for selecting and consuming foods are the product palatability and quality, which are mainly expressed as sensory properties of the food. As stated above, the ultimate goal of this study is to reduce the beany flavor and chalky mouthfeel of pure SM through the addition of other flavor-masking components. As indicated in Table 3, flavor, taste, mouthfeel and overall acceptability of SBBs improved with an increase in proportions of MN and SS. In all cases, a beverage made out of 60% SM, 25% MN and 15% SS were awarded an average value above a 4 ("somewhat like"). But beverages made from 100% SM scored significantly lower. This confirms that the undesirable flavor and

Table 3. Average score and *p*-values of sensory parameters of SBBs as influenced by percentage of MN and SS

Treatments	SM %	MN %	SS %	Flavor	Taste	Mouth feel	Overall acceptability
1	2	3	4	5	6	7	8
T1	80	12	8	4	4.1	4.2	4.2
T2	85	0	15	3.8	4.0	4.1	4.1
T3	75	25	0	4.0	4.1	4.2	3.9
T4	60	25	15	4.2	4.3	4.5	4.4
T5	85	0	15	3.8	3.9	4.1	4.1
T6	67	25	8	4.1	4.2	4.4	4.3

Table 3 – cont.

1	2	3	4	5	6	7	8
T7	75	25	0	4.0	4.2	4.3	3.9
T8	100	0	0	3.7	3.8	3.4	3.6
T9	86	6	8	4.0	4.1	4.0	4.1
T10	73	12	15	4.1	4.2	4.3	4.2
T11	100	0	0	3.6	3.7	3.3	3.5
T12	92	0	8	3.7	3.8	3.6	3.8
T13	60	25	15	4.1	4.3	4.4	4.3
T14	87	13	0	3.9	4.0	3.9	4.0
Linear model				***	***	***	***
Quadratic model				*	*	**	ns
Lack of fit				0.5	0.26	0.15	0.16
Adj. R^2				0.93	0.95	0.97	0.80

SM – soy milk, MN – mango nectar, SS – sucrose solution; ***highly significant, *significant, ns – non-significant.

mouthfeel of SM can be improved by incorporating MN and SS, instead of synthetic flavoring agents. In similar studies, decreasing the proportion of soy milk and blending in fruit and chocolate increased the sensory quality, which result in improved flavor, mouth feel and overall acceptability of the blended beverage (Rozina, 2012). Sucrose and mango nectar are added to many foods to improve sensory acceptance through increasing the sweetness of the final products, improving the color and masking the undesirable 'green bean flavor' of soybean. Therefore, blending beverages changes and enhances the overall acceptance of the beverage and this in turn enhances soy consumption (Choonhahirun and Akesowan, 2012; Madukwe and Eme, 2012; Pena et al., 2006; Trindade et al., 2001).

Optimal mixture compositions

Optimization has been defined as a process of deriving the best formulations from several components (Prinyawiwatkul et al., 1997). Based upon this, numerical optimization was conducted after assigning chemical and sensory parameters either to maximum or minimum values in the parameters in the mixes. The optimum beverage mix, made from 81% SM, 16% MN and 3% SS (desirability of 0.564), was predicted as the best combination to satisfy both nutritional requirements and sensory acceptability (Fig. 1). Protein, ether extract and carbohydrate would be 4.1%, 2.1%

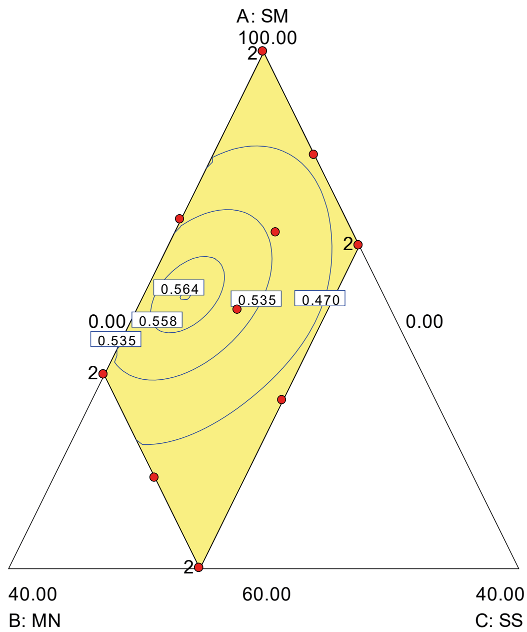

Fig. 1. The overall contour plot for best-quality SB

Table 4. Best fit quadratic model equations for different parameters of SBB

#	Response	Quadratic model equations
1	total color change	0.5A + 217.6B + 33.4C – 180.0AB + 1.8AC – 145.4BC
2	total soluble solid	2.33A + 1.97B – 41.99C + 6.91AB + 74.02AC + 53.5BC
3	moisture content	90.862A + 80.049B + 73.786C + 7.049AB + 11.289AC + 17.086BC
4	ash	0.1632A + 0.3636B – 0.9679C – 0.3730AB + 1.0544AC + 1.0608BC
5	protein	5.460A + 0.385B + 0.595C – 2.673AB – 6.547AC + 7.037BC
6	ether extract	2.358A – 2.288B – 4.014C + 3.685AB + 5.114AC + 5.680BC
7	carbohydrate	1.15A + 21.81B + 30.05C – 8.08AB – 10.21AC – 30.96BC
8	gross energy	47.69A + 67.89B + 86.21C – 9.67AB – 20.99AC – 42.48BC
9	titratable acidity	0.03876A + 0.03609B + 0.03387C – 0.08783AB – 0.04965AC – 0.17672BC
10	pH	6.97A + 6.83B + 5.56C – 0.98AB + 0.43AC + 0.92BC
11	beta-carotene	0.000735A – 0.00807B – 0.00715C + 0.014457AB + 0.005566AC + 0.029716BC
12	calcium	245.91A + 67.52B – 41.07C – 89.59AB – 3.74AC + 322.95BC
13	iron	1.84A – 1.50B – 11.94C + 1.31AB + 13.04AC + 18.01BC
14	potassium	1617A + 1253B + 11879C – 697AB – 1677AC – 12611BC
15	phytic acid	3.31A – 12.50B – 8.04C + 13.41AB + 8.15AC + 15.60BC
16	flavor	3.613A + 1.040B – 1.302C + 5.560AB + 7.331AC + 11.269BC
17	taste	3.7332A + 0.861B0.8765C + 5.988AB + 5.015AC + 8.87BC
18	mouth feel	3.354A + 1.6.3B + 4.54C + 7.095AB + 4.117AC – 1.998BC
19	overall acceptability	3.562a – 2.410B + 1.469C + 10.023AB + 6.166AC + 14.196BC

A − soy milk, B − mango nectar, C − sucrose solution.

and 4% respectively and pH will be 6.81. Ca, Fe and K would be 202, 1.5 and 1287.5 mg/100 g respectively. The beverage would show a beta-carotene concentration of 0.0012 mg/100 g. Regarding sensory properties, the SBB with components of optimized concentration would show flavor, taste, mouthfeel, and overall acceptability of 4, 4.1, 4.1 and 3.9 respectively on a 5 point hedonic scale. The overall desirability of the beverage would be 0.564.

CONCLUSIONS

Soy milk-based beverages enriched with MN and SS have a generally good nutritional and sensory quality. When all measured parameters were optimized together, the best blend ratio was obtained from the mixture of 81% SM, 16% MN and 3% SS. From this study it was concluded that it is possible to develop a product with good physicochemical and sensory qualities when soy milk is blended with mango nectar and sucrose solution. It is suitable for all age groups in developing countries where hunger and protein energy malnutrition is high. In addition, this study is beneficial to communities intolerant to lactose from cow's milk, and when it is unavailable or unaffordable.

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