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Research Article

Effect of Soymilk on the Nutritional, Textural and Sensory Quality of Pudding

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Abstract

Soy milk is an attractive alternative to cow's milk because of its high protein content, lower fat content and being free of cholesterol and lactose (milk sugar), which millions of lactose-intolerant people are incapable of digesting properly. Nowadays, plant-based food products are gaining more popularity due to several health benefits. Soybean saponins are phytosterols found in soybeans, leading to an increase in excretion and preventing absorption, resulting in body cholesterol depletion. This study aimed to develop pudding by incorporating soy milk and assessed its quality. Soybean was soaked, blanched, grinded, and filters to extract soy milk. The chemical composition of soy milk and cow milk was analyzed. Five formulae were developed for soy pudding using 0, 25, 50, 75, and 100% soy milk and named A, B, C, D, and E, respectively. Processed soy pudding was analyzed for nutritional, textural, and sensory quality. The moisture and protein contents were higher in soy milk whereas ash, fat, and carbohydrate contents were higher in cow milk. Pudding containing soy milk had a higher amount of protein than the control samples. The level of protein content for soy pudding was E>D>C>B>A. Sample A showed the lowest hardness compared with the others. Calcium, phosphorous, sodium, and zinc contents decreased (p<0.05) with the addition of soy milk. However, the opposite scenario was observed for iron, magnesium, and potassium. Moreover, soy milk fortification decreased L*-value of soy pudding and lessened viscosity relative to the control. Sensory analysis suggested that sample C (50% soy milk and 50% cow milk) and sample B (25% soy milk and 75% cow milk) were equally acceptable to consumers. So, it can be said that soy milk could be used for processing pudding at 25 and 50% levels.

Introduction

Antioxidants, dietary fiber, and phytonutrients are available in plant-based food products which are getting popularity day by day due to their health advantages. Soybeans are regarded as an important edible crop, particularly for vegans (Pimental and Pimental, 2003). Soybeans contain a high amount of protein and fat *i.e.* it contains around 21% oil content and 39% protein (on dry basis), with all the necessary amino acids except methionine (Mazumder and Hongsprabhas, 2016a). Research revealed that soy phytosterols help to lower blood cholesterol by inhibiting cholesterol absorption (Mazumder and Hongsprabhas, 2016a). These phytosterols increases the excretion and prevent absorption of cholesterol, resulting in body cholesterol depletion. Soy isoflavone is also known phytoestrogens boost the antioxidant activity and reduces blood cholesterol levels by scavenging the free radicals (Ranich et al., 2001; Shahidi, 2009). Soy isoflavones have also been shown to eliminate cholesterol from blood serum (Ijaj et al., 2018) and diminish hormone-dependent malignancies like breast cancer and prostate cancer (Mazumder and Hongsprabhas, 2016b). Soybean also contains a variety of additional nutrients, including crude and dietary fiber, vitamins, minerals, and oligosaccharides. The presence of oligosaccharides satisfies prebiotic requirements and promotes the growth of beneficial microbial pathogens in the large intestine (Joelle and Dent, 2011). Soy product consumption has been related to lowering the risk of cardiovascular disease, decreasing the risk of cancer, preventing overweight, improving bone mass density, and easing postmenopausal symptoms (Mazumder and Hongsprabhas, 2016b).

Soy milk is one of the many soy products that may be made from soybeans. Soy milk is made from soybeans that have been soaked, ground, and filtered (Nowshin et al., 2018). Soy milk is produced on a large scale in the food industry and as well as at home scales too.

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Lactose-free soy milk is ideal for vegetarians, those who cannot digest or are allergic to dairy products, and those who suffer from lactose intolerance. Soy milk is a popular substitute for cow's milk all over the world (Bus and Worsely, 2003). Soy milk also offers higher amounts of protein, iron, unsaturated fatty acids, and niacin than milk from cows and breast milk, but lower amounts of fat, carbohydrate, and calcium. Recently, people concerned about eating healthy foods. For health-conscious consumers, soy milk-based food products such as soy pudding may be an effective and efficient option.

Protein-energy malnutrition and micro-nutrient deficiency are the most chronic malnutrition problem in developing countries including Bangladesh. More than eighty percent malnourished population lives in developing countries (Mazumder, 2016). Chronic malnutrition is associated with the socio-economic condition of Bangladesh, which inhibits the purchase of nutritious food such as poultry, dairy, fruits, and vegetables. It is essential to supply high highly nutritious food with minimum production and purchasing cost such as soy pudding.

Pudding is a sweet, milk-based delicacy that is usually made using pasteurized milk. Soy pudding is a dish made from soy milk, sugar, and egg as emulsifiers. Soy pudding is low in saturated fat, cholesterol-free, and high in protein (Ojha et al., 2014). Protein, minerals like calcium and iron, and omega-3 fats are all included in soy pudding, which is easy to digest. Soy pudding is a fun twist on traditional milk pudding. Egg yolks, on the other hand, are frequently utilized as emulsifiers to prevent oil separation. An emulsifying component in egg yolks is lecithin. On the top of the droplet; lecithin produces a negatively charged emulsion that draws pro-oxidant metal ions (Tanija and Singh, 2003). Proteins, most commonly sourced from soybeans, can be used to alleviate this. The proteins adsorb at the oil/water or air/water interface, preventing coalescence of the interfacial membranes. Despite the fact that soy pudding is a low-cost protein-rich product with exceptional qualities, mechanized pudding manufacturing is still in its infancy, and most production is confined to the cottage level due to a lack of well-defined research. In light of this, the goal of this study was to optimize the soy pudding development process and investigate the effect of soy milk on the nutritional, physical, rheological, textural, and sensory qualities of soy pudding.

Materials and Methods

Raw materials

The soybeans were collected from Agora Super Shop (Dhaka, Bangladesh). The milk came from a local dairy farm in Mymensingh. Food grade $NaHCO_3$ was supplied by Mitali Chemicals, Dhaka, Bangladesh.

Preparation of soy milk

Soybean (1 kg) was soaked in a beaker containing 0.5% food-grade $NaHCO_3$ for 60 min at 60°C. The soybean-to-water ratio was kept at 1:2. Water was drained well and soaked beans were manually dehulled using both hands. Dehulled soybeans were blanched at 90°C for 10 min. The ratio of soybeans to water (containing 0.5% $NaHCO_3$) was kept at 1:2. The blanched soybean was grinded by a supper mass colloider (Masuko Sangyo Co. Ltd., Kawaguchi, Japan) and basket centrifuge (Nowshin et al., 2018). During the grinding process, hot water (100°C) was used at a 4:1 ratio (water: soybean). Soy milk was extracted after filtering through double-layer cheese cloths. Moisture, protein, ash, and fat content of extracted soy milk were measured after pasteurization (65°C for 30 min).

Processing of soy pudding

Different concentration of soy milk and cow milk was used for the preparation of soy pudding (Table 1). Soy and/or cow milk was taken in a bowl; sugar was added with it in a mould and mixed properly. The mixture was heated at 60°C for about 10 min and stirring had been carried out simultaneously throughout the whole boiling process. Then the mixture was cooled for 15 min to reach room (28±2°C) temperature. Other ingredients such as emulsifier and vanilla extract were added with the mixture containing soy milk and/or cow milk, and sugar, and stirred. The whole mixture was then heated at a temperature 50°C for about 40 min and then cooled to room temperature (28±2°C).

Table 1. Basic formulations of soy pudding on a 100 g basis

Ingredients	Sample formulations				
Basic formula	**A**	**B**	**C**	**D**	**E**
Soy milk (g)	0	25	50	75	100
Cow milk (g)	100	75	50	25	0
Egg (g)	60	60	60	60	60
Sugar (g)	30	30	30	30	30

The formulation of soy pudding is shown in flow diagram 1.

Soy milk/Cow milk (different concentration)

↓

Addition of sugar (30 g)

↓

Stirring and boiling (60° C, 10 min)

↓

Cooling (28±2°C, 15 min)

↓

Addition of emulsifier (Whole egg)

↓

Addition of vanilla extract and stirring

↓

Heating (50° C, 40 min)

↓

Cooling (28±2°C)

Flow diagram 1: Preparation of soy pudding

Proximate composition analysis

Moisture (AOAC, 2019a), ash (AOAC, 2019b), crude protein (AOAC, 2019c), and fat (AOAC, 2019d) were determined using AOAC methods employing a hot air oven, muffle furnace, Kjeldahl, and Soxhlet apparatus, respectively.

Moisture content

Oven drying method carried out for measuring moisture content. The electric balance was used to weigh a dry crucible when it was empty. Later, in the dry crucible, 5 g of sample was collected and weighed in the digital balance. The crucible containing the sample was then kept in an oven and dried overnight at 100 to 105°C. After dehydration, the crucible containing the sample was taken out from the oven and cooled in the desiccators. The moisture dish with the sample was weighed once it had cooled. The sample's moisture content was estimated using equation *i*. A set of 3 samples were dried in the oven for accuracy, and the mean moisture content was calculated.

$$\%\ Moisture = \frac{(W - X)}{Z} \times 100 \ldots\ldots\ldots\ldots\ldots (i)$$

Where, W = Crucible + sample weight (g); X = Crucible + dry sample weight (g); Z = sample weight (g)

Ash content

Moisture-free 5 g sample was taken in a porcelain crucible and burned in a gas burner to avoid loss of sample into muffle furnace at high temperature. The crucible was then placed in a muffle furnace and burned for 6 hours at 550°C. The crucible was taken from the hot air oven and allowed to cool for 5 minutes in a desiccator. The ash content had been computed using the equation below:

$$\%\ Ash = \frac{(X - Y)}{W} \times 100 \ldots\ldots\ldots\ldots\ldots (ii)$$

where, X = Ashed weight (g), Y = Crucible weight (g), and W = sample weight (g)

Protein content

3 g sample and 5 g digestion mixture were taken in a Kjeldhal flask. 25 ml of concentrated H_2SO_4 was taken in flask. Digestion was completed until the solution became clear. An aliquot (5 ml) amount was taken in a distillation flask and 40 ml of 40% NaOH solution was added. In a 100 ml conical flask 15 ml 2% boric acid solution, 10 ml of ammonia-free water, and two drops of the mixed indicator were added and set up in a distillation unit. Distillation was carried out for 40-min and titrated with 0.1 N HCl. A blank titration was also determined and deduced from titration. Crude protein was determined by multiplying with a factor of 6.25. The formula is given bellow:

% Nitrogen =

$$\frac{(\text{Titre value - blank titre}) \times \text{N of HCL} \times 14 \times \text{volume made up} \times 100}{\text{Aliquot taken for estimation} \times \text{sample taken} \times 1000} \quad .. (iii)$$

% Protein = % nitrogen × conversion factor (6.25).

Fat content

Solvent extraction was used to evaluate the fat content of the samples. The thimbles were filled with 2 g of sample. The thimbles were dropped into the Soxhlet device' fat extraction tube. The tubes' ends were connected to a Soxhlet flask. Anhydrous ether in the amount of 75 ml or so was put into the flask through the sample in the tube. The condenser was connected to the top of the fat extraction tubes. On a heater set at 70°C-80°C, the samples were extracted for about 16 hours. The heater should be set to a temperature where the ether that has volatilized condenses and drips continuously onto the sample with no noticeable loss. The thimbles were withdrawn from the device at the completion of the extraction phase, and the majority of the ether was distilled off by leaving it to settle in the Soxhlet tube. Whenever the tube was nearly full, the ether was spilled out. Through a little funnel, the ether was transferred into a small and dry (previously weight) beaker once it had achieved a small volume. Several tiny quantities of ether were used to completely rinse and filter the flasks. The ether was evaporated over a low heat steam bath and then dried at 100°C for 1 hour before being chilled and weighted.

The fat-soluble substance present in the samples was determined by the difference in weights, and the percent fat content was calculated by using equation *iv*.

$$\% \, Fat = \frac{Weight\ of\ fat}{Weight\ of\ sample} \times 100 \ldots\ldots\ldots\ldots (iv)$$

Total carbohydrate

The total carbohydrate content was calculated using the Food and Agriculture Organization's (FAO) methodologies (FAO, 2003). The carbohydrate content in the sample had not been directly determined. It was calculated by deducting the entire amount of moisture, fat, protein, and ash percentage from 100.

Mineral content analysis

The dry digestion technique was used to estimate minerals in soy milk, cow milk, and soy pudding samples. Mineral substances of importance namely calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were assessed by an ISO (2007) method, whereas macro-nutrients such as zinc (Zn),and iron (Fe) were measured using an AOAC (2016b) approved method utilizing an atomic absorption spectrophotometer (Model: AA-7000; Shimadzu, Japan). Phosphorus (P) was determined by spectrophotometry; absorbance was read at 820 nm using an Elisa Reader (Infinite 200 Pro Nano Quant) (ISO, 2006).

Rheological Measurements (Steady Shear)

Brookfield viscometer (model DV-III, Brookfield Engineering Laboratories, Inc., Middleboro, MA) had been used to estimate steady shear observations of soy pudding. The SRC (shear rate constant) was computed according to the method described in Abdoqasem et al. (2016). The computed results for SRC were 0.33. At three distinct temperatures of 32, 42, and 52°C, apparent viscosity was measured using 25 of variousrpm within the range between 20 and 200 rpm with 15 rpm increases. Shear rates ranged from 6.6/s (20 rpm) to 66.6/s (200 rpm). The apparent viscosity (N/m^2) and shear stress (N/m^2) were calculated specifically for each sample. Calculations were done according to the following equations used by Abdoqasem et al. (2016).

$SRC = (2wRb^2\ Rc^2)/\{x^2(Rc^2-Rb^2)\}$ .... (v)

SRC stands for the shear rate constant (1/s) that had been used to find out shear rate and shear stress. The radius of the vessel (in cm) is Rc, w is the angular velocity of the spindle (Rad/s), Rb is the radius of the spindle (cm), and X is the radius where the shear rate will have to be determined (usually just like Rb in cm).

$w = 2\pi N/60$ ....(vi)

Where, N has been the spindle speed in revolutions per minute.

Texture analysis

The modified Tan and Mittal approach (Tan and Mittal, 2006) was used to analyze the texture profile of soy pudding. A texture detector (TA-XT plus, Stable Micro System, UK) with nothing but a cylindrical tip having a diameter of 36 mm, 50 percent compression, and a test speed of 1.0 mm/s was used to measure the textural qualities of soymilk-enhanced soy pudding (2 cm x2 cm x2 cm) from the central section of pudding. The pre and post-speed was 2 mm/s, and the trigger force was 5.0 g. Hardness, cohesiveness, springiness, and gumminess were all assessed as textural qualities. Eventually, by designing a dual cycle in software named Texture Expert 1.05 software (Stable Microsystems), the textural features of the generated soy pudding were determined.

Color determination

A Hunter colorimeter (chromameter, Japan) had been used to determine the color values (L*, a*, and b*) of soy pudding. L* represents the lightness of soy pudding (0 = dark color, 100 = white color). Positive and negative a* values depict the red and green colors, respectively. Yellow and blue, on the other side, are reflected by positive (+) and negative (-) b* values, respectively. Three average color values were derived for each based on three multiple measurements and three duplicates.

Sensory evaluation

Sensory properties like color, flavor, texture, and overall acceptability of prepared soy puddings were evaluated by 10 semi-trained panellists on a 9-point hedonic rating scale (Amerine, 1965). The hedonic rating scale was arranged like as: 9 = extremely like, 8 = highly like, 7 = like moderately, 6 = somewhat like, 5 = neither like nor dislike, 4 = dislike slightly, 3 = moderately dislike, 2 = dislike considerably, and 1 = dislike excessively.

Statistical analysis

Using StatView (Abacus Conceptts Inc., Berkeley, CA, USA) software, the findings were statistically examined using ANOVA (analysis of variance) and Fisher's least significant difference (LSD) methods to see if there were any significant differences or not at the 5% level of significance.

Results and Discussion

Nutritional components of extracted soy milk and cow milk

Table 2 shows the nutritional composition of cow milk and extracted soy milk. Moisture and protein content was higher in soy milk than in cow milk. However, ash, fat, and total carbohydrate content were higher in cow milk than in soy milk. Ahmed et al. (2019) suggested that soy milk contained 90.01% moisture, 3.90% protein, 2.22% fat, 0.28% ash, and 3.59% total carbohydrate in soy milk whereas 87.5% moisture, 3.55% protein, 3.60% fat, 0.75% ash and 4.60% total carbohydrate in cow milk.

Seven minerals elements for instance calcium, magnesium, sodium, potassium, phosphorus, zinc, and iron were measured in cow and soy milk from two distinct sources. Table 2 depicts cow milk had statistically higher calcium (134.50 mg/100g), phosphorus (83.50 mg/100g), sodium (42.20 mg/100g), and zinc (0.57 mg/100g) than soy milk (4.69, 49.60, 11.60 and, 0.23 mg/100g, respectively). Soy milk, on the other hand, had much higher iron (1.05 mg/100g), magnesium (18.85 mg/100g), and potassium content (140.50 mg/100g) than cow milk. The findings are quite similar to Singh et al. (2019), and Mazumder and Begum (2016).The variations in the composition of soy milk might be to soy variety and agro-ecological conditions, fertilizer utilization, the extent of drying, storage condition, analysis methods, etc. For cow milk composition, it might be due to cattle spices and feed composition.

Effect of soy milk incorporation on the nutritional quality of soy pudding

Table 3 shows the nutritional quality of soy puddings prepared with or without soy milk.

Table 2. Nutritional composition of soy milk and cow milk per 100 ml

Components	Soy milk	Cow milk
Moisture %	90.01±0.02^{a}	87.5±0.05^{b}
Protein %	3.90±0.01^{a}	3.55±0.03^{b}
Fat %	2.22±0.01^{b}	3.60±0.02^{a}
Ash %	0.28±0.02^{b}	0.75±0.01^{a}
Carbohydrate %	3.59±0.03^{b}	4.60±0.02^{a}
Calcium (mg/100g)	4.69±0.07^{a}	134.50±0.06^{b}
Iron (mg/100g)	1.05±0.04^{b}	0.11±0.07^{a}
Magnesium (mg/100g)	18.85±0.01^{b}	10.0±0.09^{a}
Phosphorus (mg/100g)	49.60±0.03^{a}	83.50±0.04^{b}
Potassium (mg/100g)	140.50±0.06^{a}	133.70±0.01^{b}
Sodium (mg/100g)	11.60±0.09^{a}	42.20±0.03^{b}
Zinc (mg/100g)	0.23±0.07^{a}	0.57±0.08^{b}

Mean ± SD, for each assessment, the mean of three trials is used. Means with various superscripts in the same row proved different significantly ($p \leq 0.05$).

Table 3. Effect of soy milk incorporation on the physicochemical and nutritional quality of soy pudding

Components	Soy pudding				
	A	B	C	D	E
Moisture (%)	11.27±0.02^{a}	11.87±0.01^{b}	12.01±0.02^{b}	12.67±0.02^{d}	14.68±0.02^{e}
Protein (%)	4.90±0.02^{b}	5.40±0.02^{c}	6.05±0.01^{a}	6.65±0.01^{d}	7.01±0.01^{e}
Fat (%)	3.36±0.02^{b}	3.04±0.03^{b}	2.98±0.01^{b}	2.83±0.01^{a}	2.42±0.01^{e}
Ash (%)	2.01±0.02^{e}	1.94±0.02^{e}	1.83±0.01^{c}	1.75±0.01^{b}	1.70±0.01^{a}
Total Carbohydrates (%)	78.46±0.06^{a}	77.75±0.04^{b}	77.13±0.04^{c}	76.10±0.01^{d}	74.19±0.01^{e}
Calcium (mg/100g)	154.50±0.06^{b}	117.20±0.02^{a}	80.85±0.06^{e}	43.53±0.06^{d}	6.69±0.07^{c}
Iron (mg/100g)	0.21±0.07^{a}	0.62±0.04^{b}	1.28±0.02^{d}	1.44±0.03^{c}	1.85±0.04^{e}
Magnesium (mg/100g)	18.0±0.09^{a}	20.50±0.01^{b}	23.42±0.05^{c}	25.50±0.05^{d}	28.85±0.01^{e}
Phosphorus (mg/100g)	103.50±0.04^{b}	91.75±0.05^{a}	81.25±0.06^{d}	69.25±0.06^{c}	58.60±0.03^{e}
Potassium (mg/100g)	153.70±0.01^{b}	155.11±0.02^{a}	157.25±0.03^{c}	158.75±0.03^{e}	161.50±0.06^{d}
Sodium (mg/100g)	62.20±0.03^{b}	51.25±0.03^{a}	41.40±0.03^{c}	29.30±0.03^{d}	21.60±0.09^{e}
Zinc (mg/100g)	0.77±0.02^{b}	0.66±0.01^{a}	0.59±0.01^{c}	0.47±0.01^{d}	0.38±0.07^{e}
L*	72.85 ± 1.35^{a}	58.55 ± 1.50^{d}	57.85± 1.25^{d}	62.15 ± 0.50^{c}	67.85 ± 0.55^{b}
a*	1.85 ± 0.05^{a}	1.95 ± 0.03^{b}	1.92 ± 0.04^{b}	2.42 ± 0.05^{c}	3.92 ± 0.03^{d}
b*	29.85± 1.25^{d}	26.68± 2.25^{b}	21.45± 1.75^{c}	18.55± 1.35^{a}	17.45± 1.05^{a}

Mean ± SD, for each assessment, the mean of three trials is used. Means with various superscripts in same row proved different significantly ($p \leq 0.05$). Sample A contained 100% cow milk; Sample B was the mixture of 75% cow milk and 25% soy milk; Sample C contained an equal portion of cow milk and soy milk; Sample D was formulated with 25% cow milk and 75% soy milk; Sample E didn't contain any cow milk but 100% soy milk.

Table 3 shows that sample A (11.27%) had lower moisture content than other samples. However, the highest moisture content (14.68±0.02%) was found in sample E. The result suggested that moisture content gradually increased with increasing substitution levels of soy milk. This might be due to the higher moisture content of soy milk than cow milk (Table 2).

The protein content of sample A (4.90±0.02%) was lower than other samples and the highest (7.010±0.01%) was found in sample E. Protein content gradually increased with increasing of soy milk, as the protein content of soy milk was higher than cow milk (Table 2). For example, the recommended daily allowance (RDA) for protein in the United States (USA) and Canada is 46 and 54 g per day for women and men, respectively, or 0.80 g per kilogram of body mass to account for differences in body proportions. The population reference intake (PRI) for protein has been set at 0.83 g per kg of body mass by the European Food Safety Authority (EFSA). The SLP (stand for a safe level of protein) intake recommended by the World Health Organization (WHO) is 0.83 g per kilogram of body mass. This research suggested that 100 g of soy pudding could provide 10% of the protein requirements.

Sample A had higher fat and ash content than other samples. Fat and ash content gradually decreased with increasing substitution of soy milk, as soy milk contained a low amount of fat and ash content than cow milk. Besides, there was no considerable (p>0.05) differences between sample A and sample B for the components ash and fat. The carbohydrate content of sample E (74.19±0.01%) was lower than other samples. However, the highest carbohydrate content (78.46±0.06%) was found in sample A. The result reflects that carbohydrate content gradually decreased with increasing substitution levels of soy milk as cow milk contained more carbohydrates than soy milk.

Seven mineral substances such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), phosphorus (P), zinc (Zn), and iron (Fe) were tested from five different soy pudding samples. Table 3 indicates that sample A had the highest calcium content than control and other soy puddings. Calcium content went down significantly (p<0.05) with the incorporation of soy milk and the minimum calcium content found in sample E where there was no cow milk. As usual cow milk contains significantly (p<0.05) higher amounts of calcium than soymilk. Similarly, phosphorous, sodium, and zinc content decreased statistically with the addition of soy milk (Table 3). On the other hand, the opposite scenario was observed for iron, magnesium, and potassium as the content of these specific minerals increased with the incorporation of soy milk. Table 3 also suggested that sample A had the lowest iron (0.21±0.07mg/100g), magnesium (18±0.09 mg/100g), and potassium content (153.70±0.07mg/100g) while sample E contained the highest. These findings were close to the findings of Erkaya and Sengul (2012) and Mazumder and Begum (2016).

Table 3 demonstrates that L* (lightness) value of soy pudding increased with increasing of soy milk in the soy pudding (from 57.85to 67.85). This might be due to the isoflavone (genistein) content of soy milk. Genistein present in soy milk and soy products can inhibit non-enzymatic browning (Mazumder, 2016; Mazumder and Hongsprabhas, 2016b). Soy milk contains approximately 4-7 mg total isoflavones per 100 g with considerable variations both in composition and content (Mazumder and Begum, 2016). However, soybean and soy milk contains 4.6 and 2.0 µg/g sample, respectively (Fukutake et al., 1996). There was no significant differences (p>0.05) between sample B and sample C in terms of L* values. With the addition of soy milk, a* value of soy pudding crumb was enhanced to 3.92 (from 1.85). Crumb with 100% soy milk (sample D) had the highest a* (redness), and there was a statistical difference (p<0.05) among a* values for sample D and sample E but no substantial difference (p>0.05) between sample B and sample C. However, as the amount of soy milk increased, the crumb's b* (yellowness) rating declined. In sample A, the maximum b* (29.85) was recorded means sample are yellowish in color. Soy milk used in this study to replace cow milk for preparation of soy pudding might be less light, more reddish and less yellowish in color (Table 3) than pudding prepared form cow milk, which subsequently resulted in decreasing of lightness (L*), increasing of redness (a*) and decreasing of yellowness (b*).

Steady shear attributes

The power-law approach (*τ=kγ^n, where τ= shear stress, K= consistency co-efficient, n= flow behavior index, and γ= rate of shear) was used to describe the shear rate and shear stress scores acquired from the pudding gel's apparent viscosity statistics. The flow behavior index (n) of the pudding was n<1 when compared to other starch gels (Figure 1), showing pseudo-plastic behavior, which is a regular trait of any and all starch-containing emulsions. As a result, a lesser 'n' number indicates a rather more pseudoplastic structure. Furthermore, negatively charged polysaccharides are widely believed to raise the flow behavior index (n) of several starch-based materials. Decreased values of the consistency coefficient (k) were reported at greater soy milk doses. The inclusion of soy milk lessened viscosity relative to the control throughout all three different temperatures as the 'k' is a measure of gel viscosity, greater values of k lead to higher viscosities at reduced levels of soy milk, as indicated in figure 2. Consistency coefficient drops as shearing temperature rises (Figure 2), indicating a relationship between thixotropy and temperature, *i.e.,* viscosity lowers as temperature rises. The pseudo-plasticity of macro-molecule fluids could be attributed to the disassociation of long string molecules, resulting in a decrease in the inter-particle barrier to stream at shear settings (Nurul et al., 1999).

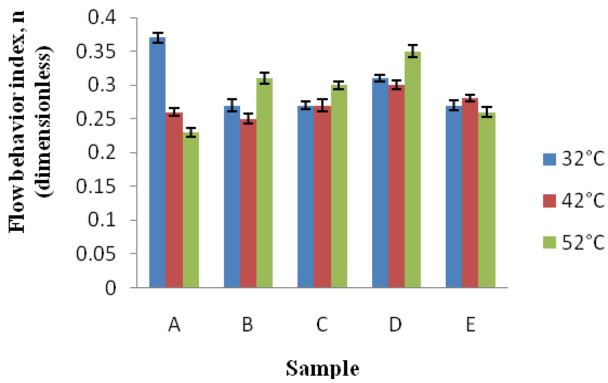

Figure 1. Pudding flow behavior index (n) fitted by the power-law* at different soy milk concentrations and temperatures. Mean ± SD = Average of three replicates for each analysis. Sample A contained 100% cow milk; Sample B was the mixture of 75% cow milk and 25% soy milk; Sample C contained an equal portion of cow milk and soy milk; Sample D was formulated with 25% cow milk and 75% soy milk; Sample E didn't contain any cow milk but 100% soy milk.

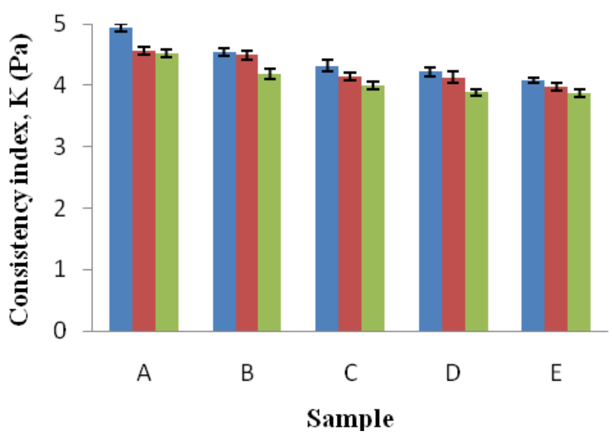

Figure 2. Pudding consistency index (K) fitted by the power-law* at different soy milk concentrations and temperatures. Mean ± SD = Average of three replicates for each analysis. Sample A contained 100% cow milk; Sample B was the mixture of 75% cow milk and 25% soy milk; Sample C contained an equal portion of cow milk and soy milk; Sample D was formulated with 25% cow milk and 75% soy milk; Sample E didn't contain any cow milk but 100% soy milk.

Effect of addition of soy milk on the texture of pudding

In comparison to the others, sample E had the highest gel hardness (65.33±2.8g) (Table 4) due to the presence of dietary fiber (0.7± 0.08 g) in the soy milk. The presence of dietary fiber increases the gel hardness. The hardness of gel is linked to both fiber matrix and the filling action of inflated fiber granules. When soy milk was added to the pudding, the amount of fiber in the blend was increased, resulting in increasing the pudding's hardness (Table 4). In comparison to the control, increasing the soy milk content resulted in a significant (p<0.05) increase in the cohesiveness of the pudding. Except for sample B, the springiness of samples was substantially greater than in sample E. Gumminess of sample E was much higher than the rest samples. The softer gel compared to the control is owing to the lack of fiber in the blends.

Table 4. Effect of soy milk on the texture of pudding

Sample	Hardness	Cohesiveness	Springiness (mm)	Gumminess (g)
A	48.38±1.5^{d}	0.65±2.0^{d}	8.75±0.45^{b}	22.71±1.3^{e}
B	51.43±2.0^{cd}	0.64±0.03^{cd}	7.95±0.30^{a}	24.93±2.9^{d}
C	56.23±2.5^{c}	0.52±0.03^{c}	9.75±0.43^{e}	16.49±1.8^{c}
D	62.35±2.6^{b}	0.50±0.05^{b}	9.72±0.46^{de}	21.45±1.6^{b}
E	65.33±2.8^{a}	0.48±2.8^{a}	8.23±0.05^{c}	31.43±3.5^{a}

Mean ± SD, for each assessment, the mean of three trials is used. Means with various superscripts in same column proved different significantly ($p \leq 0.05$). Sample A contained 100% cow milk; Sample B was the mixture of 75% cow milk and 25% soy milk; Sample C contained an equal portion of cow milk and soy milk; Sample D was formulated with 25% cow milk and 75% soy milk; Sample E didn't contain any cow milk but 100% soy milk.

Effect of soy milk on the sensory quality of the pudding

The sensory properties (color, flavor, texture, and overall acceptability) of processed soy pudding have shown in Table 5. One-way ANOVA suggested that sample A did not show any significant difference ($p>0.05$) with samples B and C in terms of color parameters. Although sample A exhibited the highest score (7.7) for color parameters followed by sample C (7.3) and B (7.1). The addition of soy milk, on the other hand, reduced the color values. Sample A (7.3) received the highest flavor score, while sample E received the lowest flavor score (5.1).Therefore, the flavor was diminished as a result of the soy milk augmentation. Sample A (7.8) obtained the highest texture score, whereas sample E received the lowest texture score (5.2). The Fisher's LSD test found that sample B and sample C were statistically similar ($p>0.05$) focusing on all sensory properties (color, flavor, texture and overall acceptability) showed in Table 5. Also, based on color and overall acceptability, samples D and E were in the same group (p>0.05). The results of total sensory evaluation ratings showed that the addition of soy milk might reduce consumer acceptability, whilst adding cow milk can have the reverse effect. However, the sensory analysis suggested that sample C (50% soy milk and 50% cow milk) and sample B (25% soy milk and 75% cow milk) were equally acceptable by consumer panels.

Table 5. Sensory evaluation of developed soy pudding

Samples	Sensory attributes			
	Color	Flavor	Texture	Overall acceptability
A	7.7 ± 0.42^{a}	7.3± 0.23^{a}	7.8± 0.06^{a}	7.6± 0.26^{a}
B	7.1 ± 0.32^{a}	6.4± 0.30^{b}	6.9± 0.11^{b}	6.8± 0.26^{b}
C	7.3 ±0.21^{a}	6.5± 0.23^{b}	6.6± 0.31^{b}	6.8± 0.42^{b}
D	6.6± 0.12^{b}	5.8± 0.22^{c}	5.7± 0.11^{c}	5.7± 0.30^{e}
E	6.5± 0.12^{b}	5.1± 0.14^{d}	5.2± 0.04^{d}	5.5± 0.23^{e}

Mean ± SD, for each assessment, the mean of three trials is used. Means with various superscripts in same column proved different significantly (p≤0.05). Sample A contained 100% cow milk; Sample B was the mixture of 75% cow milk and 25% soy milk; Sample C contained equal portion of cow milk and soy milk; Sample D was formulated with 25% cow milk and 75% soy milk; Sample E didn't contain any cow milk but 100% soy milk.

Conclusion

Moisture and protein content gradually increased with the incorporation of soy milk, because the protein content of soy milk was higher than cow milk. However, fat content decreased with increasing of soy milk in the puddings. The protein content for soy pudding was higher in the 100% soy milk-based soy pudding followed by 75, 50, and 25% soy milk-based pudding. The developed product contained substantially higher protein content than the control sample with balanced nutrition. Among seven minerals, calcium phosphorous, sodium, and zinc content decreased statistically with the addition of soy milk. On the other hand, iron, magnesium, and potassium content were increased due to the addition of soy milk in the pudding. Color analysis suggested that the addition of soy milk in the pudding decreased L* (lightness) values of soy pudding and lessened viscosity relative to the control. Texture analysis suggested that sample B and C had low hardness and soy milk addition shows better texture quality. Sensory analysis indicated that sample B and C was equally acceptable to the consumer. The overall finding of the research suggested that pudding could be processed replacing half and/or one-third of milk with soy milk. The findings may also aid in the development of technologies to diversify the use of soy milk by food processors, particularly dairy manufacturers. *In vivo* study may further need to find the health response of the consumer.

Author's contributions

Md. A. R. Mazumder and Abdullah Iqbal conceptualized and supervised the work. Md. A. R. Mazumder, Md. Ahmadul Islam and Farzana Akter were involved in manuscript writing, editing, and data analysis. Abdur Rahim performed laboratory experiments and data collection.

Competing interests

The authors have declared that no competing interests exist.

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