Physicochemical and sensory properties of ice cream prepared using sweet lupin and soymilk as alternatives to cow milk

Abebe Mengist Asres#, Henock Woldemichael Woldemariam#b, and Feyera Gobena Gemechu#b

#Department of Human Nutrition and Food Science, Debre Markos University, Debre Markos, Ethiopia; #Department of Food Process Engineering, Biotechnology & Bioprocess Centre of Excellence (Biocenex), Addis Ababa Science and Technology University, Addis Ababa, Ethiopia

ABSTRACT
Sweet lupine and soybean are legumes of high prospects as functional foods due to their rich protein content and low levels of fat, which sparked increased interest in incorporating these ingredients in food product development. This study aimed to investigate the effect of different levels of sweet lupine and soymilk substitution on the physicochemical and sensory properties of vanilla-flavored ice cream. Characterization of raw materials revealed that higher protein content was obtained in sweet lupine (5.86%) than in soymilk (4.83%) and cow milk (3.40%). However, the crude fat content of sweet lupine was much lower than cow milk and soymilk with values of 1.21%, 4.40% and 5.70%, respectively. Ice cream formulated from sweet lupine exhibited protein content ranging from 4.27 to 4.79% while maximum protein content of 4.39% was obtained for soymilk ice cream. The crude fat content of soymilk ice cream was higher than the sweet lupine ice cream with values of 7.47% and 6.6%, respectively. Formulation of soymilk and sweet lupine ice cream was effective as improved overrun of 84.05% was obtained when compared to 83% of the ice cream made from cow milk. The melting resistance for soymilk:cow milk and for sweet lupine milk:cow milk ice creams at different blend ratios ranged from 83.01 to 84.50% and 83.23 to 84.40%, respectively. The melting resistance increased as the amount of soy and sweet lupine milk increased. Sensory attributes of the formulated ice cream samples were evaluated and the taste and texture were reported to be similar to the ice cream made from cow milk up to 25% replacement. However, the ice cream preference of the panelists decreased with increased addition of soy and sweet lupine. As a result, ice creams made from soymilk and sweet lupine could be utilized as a better alternative to cow milk ice creams.

Introduction
Market demands in different milk alternatives are in the rise in current years.¹,² Due to increased change of lifestyle, special demand of diets and functional foods popularity, milk alternatives are attracting attention recently.³ Substitutes of milk in formulated food products are derived either from plants such as cereal, legume or nut-based milk⁴ or plant-based food byproducts (Iriondo-Dehond, Miguel and Del Castillo, 2018; Gemechu F G, 2020). There are growing commercially available milk alternatives having significant physicochemical properties.⁴
Lupine and soybean milk are among the alternative constituents of animal product source foods such as cheese, yogurt and ice cream.\textsuperscript{[6–8]} Ice cream is among the dairy products that are increasingly concerned with milk replacement.\textsuperscript{[9]} Ice cream is a milk, fat, sugar, stabilizer, emulsifier mixture and often contains aromatic and coloring elements.\textsuperscript{[10]} The ingredients used in their preparation are different for the composition of the ice cream. The composition of healthy ice cream is 12% milk fat, 14% milk solids not fat, 15% sugar, 0.2% stabilizer, 6.2% emulsifier, 55% to 64% water from milk or other flavoring compounds.\textsuperscript{[11]}

The acceptance by consumers of ice cream largely depends on the chemical composition, texture, consistency, melting resistance and taste. Some people cannot value the smooth texture and ice cream richness due to the presence of cow’s milk. Cow’s milk is the second most popular food allergy, mostly in infants, according to the American Academy of Allergy Asthma & Immunology.\textsuperscript{[12]} Although the product picture of cow milk is even more well-thought-of than plant milk, as shown in studies,\textsuperscript{[13]} an increasing consumer’s preference of milk alternatives is due to a variety of factors, including lactose intolerance, environmental protection, lifestyle and healthcare.\textsuperscript{[13,14]} Intolerance to lactose and milk allergies is becoming global issues. Food businesses have tried to change their recipes but preserved their original flavor, texture and to give customers the food they typically do not get used to. Since the milk of cows is a popular allergen, milk substitutes are needed which can preserve the aroma and texture of ice cream.\textsuperscript{[4][15][16]}

There has also been a great deal of emphasis on the processing of functional foods including certain plant sources of related food properties such as soymilk. Studies show that future ice cream integration leads to a consumer demand brand with better functional and physicochemical properties.\textsuperscript{[17]} The use of soymilk in the formulation of ice cream contributes to a unique balanced, nutritious product. In addition to being an independent substitute and an appropriate replacement for cow’s milk, soymilk can also be used in the development of dairy derivatives and ice cream to fix milk deficit.\textsuperscript{[18]} The proteins content of soya milk and cow’s milk (3.5–4.0%) are identical and are close to their pattern of amino acid, but soymilk is sulfur deficient in the amino acid content. Soymilk provides around 60 to 90% of the nutrient content of cattle and has similar nutritional value to the cow’s milk value but contains slightly added quantities of methionine.\textsuperscript{[19]}

Soy protein offers a range of functionalities such as water retention, binding and emulsification.\textsuperscript{[20]} The soy cream formulation has high digestibility and is free of lactose. For people, in particular people allergic to cow’s milk, with diabetes, and who have allergy to lactose and cannot use normal ice cream, this may be a safer alternative.\textsuperscript{[18]}

Lupine is known to be a convenient alternative to other plant legumes, because it comprises similar amounts of amino acid pattern proteins to soybean. New and affordable food sources, among which lupine is a potential protein food, are on the increase.\textsuperscript{[21]} As a food product, lupine has the benefit to be a higher ingredient for dietary fiber (−28%) compared with soya bean (−19%).\textsuperscript{[22]} The isolates of the lupine protein are strong emulsions and have important features in functional ingredients and its polysaccharides have a great deal of promise for usage as a nutraceutical and functional ingredient with therapeutic efficacy.\textsuperscript{[23,24]} Lupine and other underused legumes are previously tested for their nutritional composition.\textsuperscript{[25]} However, there is only limited scientific experiment of lupine incorporation in ice cream making so far.

Plant-based milks are colloidal systems made up of large dispersed particles like fat globules, solid particles from raw materials, proteins, and starch granules, which make it difficult to obtain a stable product that can be stored for long periods of time due to solid particle sedimentation or settling. The size of dispersed phase particles determines the stability of plant-based milk. Various strategies can be used to improve the stability of plant-based milk by lowering the size of dispersed phase particles. Similarly, in order to be acceptable by consumers, soymilk and sweet lupine incorporation into emulsions of ice cream are required to exhibits better properties. Particularly their emulsion property which also affects the final product’s texture is due to the protein nature as enhanced by different techniques.\textsuperscript{[26–28]}

The current study was motivated by the belief that adding other high-protein ingredients to ice cream can make it healthier and more beneficial to one’s health with improved physico-chemical and sensorial properties. Even though attempts have been made over the years to develop better
alternatives to cow’s milk due to increasing pricing of cow’s milk and its products, simultaneous evaluation of ice cream formulation from soymilk and sweet lupine milk with respect to product properties is limited. The purpose of this study was therefore to assess effect of adding fiber and protein-rich soymilk and sweet lupine milk to ice cream on the qualities of resultant formulation. Efforts were made over the years to develop cheaper alternatives to cow milk due to the rising prices of cow milk and its components, despite their high nutritional content in terms of proteins. Milk replacements have been demonstrated to be effective in studies.

Materials and methods

Raw material collection

Soy bean and sweet lupine were collected from Adet Agricultural Research Center and milk and other ingredients were collected from Bahir Dar local market in Ethiopia.

Raw materials preparation

For 18 h at ambient temperature both soy bean and sweet lupine had been cleaned, weighed, washed and soaked in water. Once soaking, the soybean and the sweet lupine were repeatedly rinsed and drained with cold water. The amount of water needed to produce the milk was weighed back. A soy bean/sweet lupine-to-water ratio of 1:7 was used to prepare soy and sweet lupine milk for molten grinding (Model: JB/T8680-2008, China). The mix was then filtered and the filtrate was boiled for 10 minutes.

Ice cream processing

Liquid ingredients of soymilk, sweet lupine and cow’s milk were blended and heated up at temperatures of about 49°C. The other ingredients of ice cream were blended and slowly added to the liquid ingredients by properly extracting them in order to achieve a uniform mixing with a mixer at 1000 to 10 minutes (Model: SWFS1.1–00, China). Special pasteurizer (Model: HMP 2000, UK) was used for pasteurizing the ice cream mix at 70°C for 15 minutes. Furthermore, the ice cream mix was homogenized at 200 bar for 5 minutes using a homogenizer (Model: FT9-A, England). The mixture was refreshed and aged at 4°C for 12 h, and vanilla flavor was added at a rate of 5 ml/l. In a freezer (Model: LH44/2GC-2-2DS, UK), batch type, three kilograms (3 kg) of ice cream mix was frozen at −4 to −5°C for 10 minutes. The ice cream was kept overnight at −26°C in a deep freezer for hardening. Mixed samples have been taken prior to freezing to analyze the different physicochemical properties.

Physicochemical determination

Proximate analysis

Standard methods of Association of Official Analytical Chemists AOAC (2000) were used for evaluating the moisture, raw protein, crude fat, ash, crude fibers and total carbohydrates.

Total solids

Samples were weighed into a previously weighted moisture dish. It was first evaporated to dryness in drying oven (Model: DHG-9140, China) at 105°C for 3 h. It was refreshed and weighed in the dryer. For final drying, the weighed sample was returned to the oven. It was then cooled and measured at an hourly interval until there was no weight difference observed.

Solid -nonfat (SNF)

The SNF was estimated by difference method. It was calculated using Equation (1)
\[
\% \text{SNF} = \% \text{TS} - \% \text{Fat} \tag{1}
\]

where; TS is total Solids

**Overrun**

Overrun refers to the quantity of ice cream that is air absorbed into the product during the freezing process in order to expand the product. This expansion depends on both the cream quality and the process of making ice cream. The higher the percentage of the overrun, the higher air is absorbed into it and thus the lighter the ice cream is. With less absorbed air into the cream however, dense ice cream is resulted from the process. Equation (2) is used to calculate overrun of the samples of ice cream.\[30\]

\[
\% \text{Overrun} = \left(\frac{\text{Volume} (m^3 \text{of ice cream}) - \text{Volume} (m^3 \text{of mix})}{\text{Volume} (m^3 \text{of mix})}\right) \times 100\% \tag{2}
\]

**Melting resistance**

From each formulated ice cream, 30 grams of samples were placed at the top of the bottle in a Buchner funnel and allowed to melt at ambient temperature (24 ± 1°C) for 15 minutes.\[11\] Thereafter, the dipped volume was weighed and Resistance to melting was achieved with the aid of Equation (3):

\[
\text{Melting resistance} \% = \left(\frac{A_1 - A_2}{A_1}\right) \times 100\% \tag{3}
\]

where; A₁ and A₂ are the weight of initial sample and melted sample, respectively.

**Sensory evaluation**

The formulated ice cream samples were subjected to sensory evaluation using 15 semi-trained panellists. The 7-point hedonic scale (7 – like extremely, 4 – neither like nor dislike, 1 – dislike extremely) was used. Accordingly, the appearance, taste, flavor, texture and overall acceptability of ice cream quality have been evaluated.\[30\]

**Data analysis**

The experiment was set in a factorial design involving types of milk (soy milk/sweet lupine milk and cow milk) and blending ratio with five levels (0:100, 25:75, 50:50, 75:25 and 100:0). All experiments and analyses were conducted in triplicates. Triplicate data collected for physicochemical and sensory properties were subjected to ANOVA and means were compared for their significance at \(p < .05\) using Statistical Analysis System (SAS Institute, Cary, NC, USA) version 9.0. Values are expressed as mean ± standard deviation.

**Results and discussion**

**Physicochemical properties of raw materials and ice cream samples**

Before production of ice cream samples, the basic raw materials were analyzed for various physicochemical compositions. Table 1 compares the proximate compositions of cow milk, sweet lupine milk and soy milk.

Different soy/sweet lupine milk and cow milk blend ice cream samples were analyzed for their physicochemical properties immediately after formulations are developed. Total solids, solid-nonfat, moisture, crude protein, fat, ash, carbohydrates, overrun and melting resistance were analyzed, the results of which are presented in Tables 2 and 3.
Table 1. Proximate compositions of cow milk, soymilk and sweet lupine milk.

|                     | Cow milk | Soymilk | Sweet lupine milk |
|---------------------|----------|---------|-------------------|
| Moisture            | 87.23 ± 0.50 | 86.74 ± 0.80 | 85.43 ± 0.46     |
| Crude protein       | 3.40 ± 0.30  | 4.83 ± 0.51  | 5.86 ± 0.38      |
| Crude fat           | 4.40 ± 0.52  | 5.70 ± 0.30  | 1.21 ± 0.23      |
| Ash                 | 0.65 ± 0.14  | 0.94 ± 0.34  | 0.83 ± 0.71      |
| Total carbohydrate  | 4.32 ± 0.37  | 1.79 ± 0.49  | 6.67 ± 0.45      |

Table 2. Physicochemical composition of soy and cow milk blend ice creams.

| Physicochemical Properties (%) | Blend ratios of soy milk to cow milk |
|--------------------------------|--------------------------------------|
|                                | 0:100  | 25:75 | 50:50 | 75:25 | 100:0 |
| Total solids                   | 31.34 ± 0.29<sup>a</sup> | 34.04 ± 0.01<sup>b</sup> | 31.07 ± 0.02<sup>c</sup> | 34.07 ± 0.06<sup>d</sup> | 34.13 ± 0.00<sup>e</sup> |
| Solid-nonfat                   | 24.21 ± 0.49<sup>b</sup> | 27.03 ± 0.02<sup>c</sup> | 23.95 ± 0.04<sup>d</sup> | 26.61 ± 0.06<sup>e</sup> | 26.72 ± 0.09<sup>f</sup> |
| Moisture                       | 69.00 ± 0.50<sup>a</sup> | 69.0 ± 0.04<sup>b</sup> | 68.93 ± 0.02<sup>c</sup> | 65.90 ± 0.10<sup>d</sup> | 65.87 ± 0.00<sup>e</sup> |
| Crude protein                  | 4.27 ± 0.01<sup>c</sup> | 4.31 ± 0.20<sup>d</sup> | 4.33 ± 0.07<sup>e</sup> | 4.37 ± 0.08<sup>f</sup> | 4.39 ± 0.01<sup>g</sup> |
| Crude fat                      | 6.80 ± 0.02<sup>c</sup> | 7.01 ± 0.01<sup>d</sup> | 7.12 ± 0.02<sup>e</sup> | 7.46 ± 0.01<sup>f</sup> | 7.47 ± 0.09<sup>g</sup> |
| Ash                            | 0.75 ± 0.02<sup>c</sup> | 0.92 ± 0.02<sup>d</sup> | 0.51 ± 0.00<sup>e</sup> | 1.02 ± 0.01<sup>f</sup> | 1.19 ± 0.06<sup>g</sup> |
| Crude fiber                    | ND<sup>h</sup> | 0.14 ± 0.01<sup>i</sup> | 0.16 ± 0.01<sup>j</sup> | 0.23 ± 0.01<sup>k</sup> | 0.28 ± 0.02<sup>l</sup> |
| Total carbohydrate             | 19.20 ± 0.50<sup>c</sup> | 18.80 ± 0.23<sup>d</sup> | 19.11 ± 0.03<sup>e</sup> | 21.25 ± 0.18<sup>f</sup> | 21.37 ± 0.08<sup>g</sup> |
| Overrun                        | 83.01 ± 0.00<sup>a</sup> | 83.10 ± 0.01<sup>b</sup> | 83.17 ± 0.00<sup>c</sup> | 83.25 ± 0.02<sup>d</sup> | 83.32 ± 0.01<sup>e</sup> |
| Melting resistance             | 83.01 ± 0.17<sup>a</sup> | 83.67 ± 0.01<sup>b</sup> | 83.90 ± 0.00<sup>c</sup> | 84.32 ± 0.08<sup>d</sup> | 84.50 ± 0.10<sup>e</sup> |

ND: not detected. Means with different superscript letters within a row are significantly different at p < .05.

Table 3. Physicochemical composition of sweet lupine and cow milk blend ice creams.

| Physicochemical Properties (%) | Blend ratios of sweet lupine milk to skim milk |
|--------------------------------|-----------------------------------------------|
|                                | 0:100  | 25:75 | 50:50 | 75:25 | 100:0 |
| Total solid                    | 31.34 ± 0.29<sup>c</sup> | 33.54 ± 0.06<sup>b</sup> | 33.67 ± 0.02<sup>c</sup> | 34.14 ± 0.02<sup>d</sup> | 34.33 ± 0.02<sup>e</sup> |
| Solid-nonfat                   | 24.54 ± 0.30<sup>d</sup> | 26.76 ± 0.07<sup>c</sup> | 26.94 ± 0.02<sup>d</sup> | 27.45 ± 0.03<sup>e</sup> | 27.72 ± 0.10<sup>f</sup> |
| Moisture                       | 69.00 ± 0.48<sup>a</sup> | 67.88 ± 0.04<sup>b</sup> | 66.81 ± 0.15<sup>c</sup> | 66.66 ± 0.03<sup>d</sup> | 66.55 ± 0.05<sup>e</sup> |
| Crude protein                  | 4.27 ± 0.01<sup>c</sup> | 4.29 ± 0.01<sup>d</sup> | 4.26 ± 0.01<sup>e</sup> | 4.42 ± 0.04<sup>f</sup> | 4.49 ± 0.01<sup>g</sup> |
| Crude fat                      | 6.80 ± 0.02<sup>c</sup> | 6.78 ± 0.01<sup>d</sup> | 6.73 ± 0.03<sup>e</sup> | 6.68 ± 0.04<sup>f</sup> | 6.60 ± 0.10<sup>g</sup> |
| Ash                            | 0.75 ± 0.01<sup>c</sup> | 0.77 ± 0.01<sup>d</sup> | 0.79 ± 0.00<sup>e</sup> | 0.90 ± 0.00<sup>f</sup> | 0.98 ± 0.00<sup>g</sup> |
| Crude fiber                    | ND<sup>h</sup> | 0.13 ± 0.01<sup>i</sup> | 0.18 ± 0.01<sup>j</sup> | 0.22 ± 0.02<sup>k</sup> | 0.30 ± 0.02<sup>l</sup> |
| Total carbohydrate             | 19.19 ± 0.48<sup>c</sup> | 20.28 ± 0.06<sup>d</sup> | 21.38 ± 0.10<sup>e</sup> | 21.34 ± 0.03<sup>f</sup> | 21.38 ± 0.10<sup>g</sup> |
| Overrun                        | 83.01 ± 0.01<sup>a</sup> | 83.58 ± 0.03<sup>b</sup> | 83.75 ± 0.03<sup>c</sup> | 83.97 ± 0.01<sup>d</sup> | 84.05 ± 0.02<sup>e</sup> |
| Melting resistance             | 83.231 ± 0.17<sup>c</sup> | 83.58 ± 0.03<sup>d</sup> | 83.86 ± 0.03<sup>e</sup> | 84.19 ± 0.06<sup>f</sup> | 84.40 ± 0.02<sup>g</sup> |

Means with different superscript letters within a row are significantly different at p < .05.

The total solids for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 31.34 to 34.13% (Table 2) and 31.38 to 34.33% (Table 3), respectively. The samples were significantly different at p < .05 and percentage total solids increased in all the samples as the proportion of soy and sweet lupine milk increased. Abdullah et al., (2003) reported maximum amount of 34.19% total solids to which the findings of the current study are comparable. Insufficient ice cream solutes create poor texture and weak body. Total ice cream solids play a major role in ice cream consistency. Poor texture can result if present solids are present in excess, while low content can lead to a coarse texture and ice crystal formulation.

The solids-nonfat for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 24.21 to 26.72% (Table 2) and 24.54 to 27.72% (Table 3), respectively. As the proportion of soy and sweet lupine milk increased, solid-nonfat increased. The highest value (27.72%) was recorded for the sample of 100% lupine milk ice cream, while the value of solid-nonfat of 100% cow milk was found to be lower (24.21%).
The percentage moisture content for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios were ranged from 65.871 to 69.00% (Table 2) and 66.55 to 69.00% (Table 3), respectively. The moisture contents of all samples of ice creams were significantly different at p < .05. According to, the moisture content of ice cream ranged from 55 to 64% which may potentially originate from the milk. The findings of this research are on the upper range of values reported by the authors. The moisture content of ice cream decreased as the quantity of soymilk and sweet lupine milk proportion increased with cow milk in all the samples of ice cream. This meant that the soy and sweet lupine milk contributed to reduce the moisture content of the ice cream samples than the cow milk. This was due to the low moisture content of soy and sweet lupine milk. However, the moisture content of soymilk ice cream was found to be lower than sweet lupine milk ice cream.

The crude protein content for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 4.27 to 4.40% (Table 2) and 4.27 to 4.49% (Table 3), respectively. With increasing levels of soymilk, the protein content increased due to a higher protein content of soymilk (3.6%). Bisla et al., (2012) similar findings. Samples of ice cream formulated from 100% sweet lupine milk had the highest percentage protein content. Pereira et al., (2011) found in a related study that the addition of extracts of soymilk rather than skim milk raises protein content, which is attributed to the high level of soy protein extract. The reason for ice cream having the highest protein content in the present study could be the substantial amount of protein contained in sweet lupine milk that added up to the protein of the cow milk. Protein helps to incorporate air into the mixture facilitating the formation of small air bubbles and modify the texture of ice cream. It also helps in emulsifying the fat by suspending the fat molecules in the mixture.

The crude fat content for soymilk to cow milk and for sweet lupine milk to cow milk ice cream samples at different blend ratios ranged from 6.80 to 7.47% (Table 2) and 6.60 to 6.80% (Table 3), respectively, which comes mainly from the milk. The samples had a significant difference in the fat content at p < .05. The 100% soymilk ice cream showed comparatively high fat content of 100% (7.41 ± 0.09) implying that soymilk extract contains high fat compared to cow's milk (Table 2). The current finding comply with studies of Abdullah et al., (2003) who indicated that samples containing skim milk have low fat compared to soymilk samples. As the proportion of soymilk increases, the fat content of the ice cream samples increase. Milk fat gives ice cream a rich flavor, color, body and texture. Fat affects all aspects of food perception including appearance and mouth feel.

The ash content for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 0.75 to 1.19% (Table 2) and 0.752 to 0.98% (Table 3), respectively. According to Umelo et al., (2014), the ice cream samples’ ash content range from 0.60 to 1.71% and their report is correlated with the results of this analysis. Ash content for all the samples was not significantly different at p < .05. The 100% soymilk ice cream sample had the maximum amounts of ash up to 1.19% and a sample formulated from 100% cow milk ice cream was the least detectable. As the proportion of soy/sweet lupine milk blend with cow's milk increases, the ash content value increased. This indicates that ash content of soymilk is greater than that of cow milk.

The crude fiber content for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 0.00 to 0.28% (Table 2) and 0.00 to 0.30% (Table 3), respectively. For all samples, the content of crude fibers was not significantly different at p < .05. The crude fiber content of ice cream increased as the quantity of soy/sweet lupine milk increased. Most of the results in this study are in line with the results of Umelo et al., (2014) who reported that crude fiber content of ice cream samples derived from cow milk and tigernut ranged to be from 0.03 to 0.25%.

The carbohydrate content for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 19.186 to 21.367% (Table 2) and 19.186 to 21.38% (Table 3), respectively. The samples were significantly different at p < .05. The total ice cream
carbohydrates were the highest in formulations made from 100% sweet lupine milk, with a mean value of 21.34, whereas samples of ice cream made from 100% cow milk, was found to contain 19.19 (Table 3).

The overrun for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 83.01 to 83.32% and 83.01% to 84.05% (Table 3), respectively. All the samples were significantly different at p < .05. Hui et al., (2004) estimated that the normal ice cream overrun range is 60 to 90%, comparable to the results of the current work. The overrun increases with the rise in the proportion of soy and lupine milk.

The melting resistance for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 83.01 to 84.50% (Table 2) and 83.23 to 84.40% (Table 3), respectively. All the samples were significantly different at p < .05. The melting resistance increased as the amount of soy and sweet lupine milk increased in ice cream production. These results were similar to the findings of Bahramparvar et al., (2009) who reported that melting resistances were significantly different (p < .05), ranging from 40.01 to 98.35%. This result indicate that melting resistance of the ice creams improve as the proportion of the soymilk and sweet lupine milk increases. This could be due to the plant fibers, which could result in a thicker, more pleasant dessert that takes longer to melt. As a result, particularly in hot weather, this would allow for a more relaxing and delightful eating experience.\textsuperscript{[32]}

Sensory properties of ice cream

Samples of ice cream were stored overnight in refrigerator at −26°C prior to sensory evaluation and were served (~50 g) under normal white fluorescent lighting for panelists. The samples were assessed for their appearance, taste, flavor, texture and overall acceptability as presented below.

The appearance for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 3.83 to 6.50% (Table 4) and 4.03 to 6.50% (Table 5), respectively. The samples were significantly different at p < .05. Ice crystals, air cells, fat globules, unfrozen liquid protein and gel structure contribute toward the appearance of ice cream. The taste for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 3.80 to 6.40% (Table 4) and 3.70 to 6.40% (Table 5) which comes from the milk or other ingredients, respectively. The samples were significantly different at p < .05. Results showed that taste of soy/sweet lupine milk blend ice cream increased with the increase of quantity of cow milk.

### Table 4. Mean scores of sensory attributes of soymilk to cow milk ice creams.

| Sensory Attributes | Blend ratios of soy milk to cow milk | 0:100 | 25:75 | 50:50 | 75:25 | 100:0 |
|--------------------|-------------------------------------|-------|-------|-------|-------|-------|
| Appearance         |                                     | 6.50 ± 0.01\textsuperscript{a} | 6.03 ± 0.52\textsuperscript{b} | 5.90 ± 0.51\textsuperscript{b} | 4.63 ± 0.35\textsuperscript{c} | 3.83 ± 0.35\textsuperscript{d} |
| Taste              |                                     | 6.40 ± 0.00\textsuperscript{a} | 6.00 ± 0.51\textsuperscript{b} | 5.73 ± 0.49\textsuperscript{b} | 4.86 ± 0.46\textsuperscript{c} | 3.80 ± 0.51\textsuperscript{d} |
| Flavor             |                                     | 6.60 ± 0.00\textsuperscript{a} | 6.20 ± 0.51\textsuperscript{b} | 6.06 ± 0.51\textsuperscript{b} | 4.87 ± 0.45\textsuperscript{c} | 4.00 ± 0.41\textsuperscript{d} |
| Texture            |                                     | 6.70 ± 0.02\textsuperscript{a} | 6.43 ± 0.44\textsuperscript{a} | 6.33 ± 0.34\textsuperscript{a} | 5.30 ± 0.41\textsuperscript{b} | 4.16 ± 0.32\textsuperscript{c} |
| Overall Acceptability |                                 | 6.60 ± 0.00\textsuperscript{a} | 6.13 ± 0.51\textsuperscript{b} | 6.00 ± 0.50\textsuperscript{b} | 4.93 ± 0.49\textsuperscript{c} | 4.07 ± 0.52\textsuperscript{d} |

Means with different superscript letters within a row are significantly different at p < .05.

### Table 5. Mean scores of sensory attributes of sweet lupine milk to cow milk ice creams.

| Sensory Attributes | Blend ratios of sweet lupine milk to cow milk | 0:100 | 25:75 | 50:50 | 75:25 | 100:0 |
|--------------------|-----------------------------------------------|-------|-------|-------|-------|-------|
| Appearance         |                                               | 6.50 ± 0.01\textsuperscript{a} | 6.08 ± 0.02\textsuperscript{b} | 5.82 ± 0.22\textsuperscript{b} | 4.82 ± 0.07\textsuperscript{c} | 4.03 ± 0.14\textsuperscript{d} |
| Taste              |                                               | 6.40 ± 0.00\textsuperscript{a} | 6.01 ± 0.01\textsuperscript{a} | 5.53 ± 0.08\textsuperscript{b} | 4.82 ± 0.45\textsuperscript{c} | 3.70 ± 0.36\textsuperscript{d} |
| Flavor             |                                               | 6.60 ± 0.00\textsuperscript{a} | 5.96 ± 0.34\textsuperscript{a} | 6.01 ± 0.51\textsuperscript{b} | 4.77 ± 0.15\textsuperscript{c} | 4.20 ± 0.01\textsuperscript{d} |
| Texture            |                                               | 6.70 ± 0.02\textsuperscript{a} | 6.25 ± 0.03\textsuperscript{a} | 6.22 ± 0.04\textsuperscript{b} | 5.25 ± 0.21\textsuperscript{b} | 4.24 ± 0.10\textsuperscript{c} |
| Overall Acceptability |                                               | 6.60 ± 0.00\textsuperscript{a} | 6.10 ± 0.03\textsuperscript{b} | 6.12 ± 0.02\textsuperscript{b} | 4.83 ± 0.07\textsuperscript{c} | 4.21 ± 0.31\textsuperscript{d} |

Means with different superscript letters within a row are significantly different at p < .05.
The flavor for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 4.00 to 6.60% (Table 4) and 4.20 to 6.60% (Table 5) which comes from the milk or other ingredients, respectively. The samples were significantly different at p < .05.

The texture for soymilk:cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 4.16 to 6.70% (Table 4) and 4.24 to 6.70% (Table 5), respectively. Ice cream solids play a major role in ice cream consistency. If they are high, the curding texture is obtained, whereas low content could lead to the formation of ice crystals and coarse texture. Ice cream texture is specifically correlated with the structure. Air cells arrangement, ice crystal, lactose and fat clumps affect the structure of an ice cream. A smooth texture indicates that small ice and air crystals are uniform, and that no noticeable crystals are present while tasting. The overall acceptability for soymilk: cow milk and for sweet lupine milk:cow milk ice cream samples at different blend ratios ranged from 4.07 to 6.60% (Table 4) and 4.21 to 6.60% (Table 5), respectively.

**Conclusion**

Different types of ice creams were formulated from soymilk/sweet lupine milk and cow milk with different blend ratios. Physicochemical analysis of ice cream samples indicated that there was an increase in crude protein, crude fat, ash, crude fiber, and total carbohydrate content with increase in the amount of soymilk/sweet lupine milk in the blend. The newly formulated soymilk and sweet lupine milk-based ice cream exhibited a better melting resistance, a property that adds value for the consumers, providing handling convenience and longer enjoyment of the ice cream without melting. Moreover, the overrun of the formulations was found to be enhanced while techniques of the process need to be further studied to optimize it. Ice creams made with incorporated soymilk and sweet lupine milk therefore could be used by the community as these have comparable overall acceptability. It can be concluded that soymilk and sweet lupine milk can be used for the preparation of frozen desserts especially ice cream with acceptable sensorial appearance, taste, flavor, texture and overall acceptability with enhanced melting resistance. As a result of this research, processors can assist provide low-cost, nutritional modern alternatives to milk-allergic people, as well as alternative goods for religious organizations who abstain from eating animal-based foods during fasting periods.

**Acknowledgments**

The authors would like to acknowledge the Faculty of Chemical and Food engineering for providing laboratory facilities and the School of Research and Postgraduate Studies of Bahir Dar Institute of Technology for its support.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**ORCID**

Henock Woldemichael Woldemariam [http://orcid.org/0000-0001-8764-4834](http://orcid.org/0000-0001-8764-4834)

**References**

[1] Pontonio, E. Rizzello, C. G. Milk Alternatives and Non-Dairy Fermented Products: Trends and Challenges. *Foods*. 2021 Jan, 10(2), 222. doi:10.3390/foods10020222.

[2] Aydar, E. F., Tutuncu, S., and Ozcelik, B. Plant-based Milk Substitutes: Bioactive Compounds, Conventional and Novel Processes, Bioavailability Studies, and Health Effects. In *Journal of Functional Foods*. Vol. 70Elsevier Ltd 103975.Jul. 01, 2020 10.1016/j.jff.2020.103975.
[3] and Hayta, M. Effect of Soymilk Substitution on the Rheological and Sensory Properties of Salep (Traditional Turkish Milk Beverage). *International Journal of Food Properties*. 10.3,413–420.Jul 2007 10.1080/10942910600813596.

[4] Sethi, S. Tyagi, S. K. Anurag, R. K. Plant-based Milk Alternatives an Emerging Segment of Functional Beverages: A Review. *J. Food Sci. Technol.* 53,9, Springer India 3408–3423.Sep. 01, 2016 10.1007/s13197-016-2328-3.

[5] Jeske, S. Zannini, E. Arendt, E. K. Evaluation of Physicochemical and Glycemic Properties of Commercial Plant-Based Milk Substitutes. *Plant Foods for Human Nutrition*. 2017 Mar, 72(1), 26–33. doi:10.1007/s11301-016-0583-0.

[6] Al-Saedi, N. Agarwal, M. Islam, S. Ren, Y. L. Study on the Correlation between the Protein Profile of Lupin Milk and Its Cheese Production Compared with Cow’s Milk. *Molecules* 2021, 268, 2395 10.3390/MOLECULES26082895. Apr. 2021

[7] Al-Saedi, N. Agarwal, M. Ma, W. Islam, S. Ren, Y. Study on Effect of Extraction Techniques and Seed Coat on Proteomic Distribution and Cheese Production from Soybean Milk. *Molecules* 2020, 2514, 3237 10.3390/MOLECULES25143237. Jul. 2020

[8] Vogelsang-O’Dwyer, M. Sahin, A. W. Zannini, E. Arendt, E. K. Physicochemical and Nutritional Properties of High Protein Emulsion-type Lupin-based Model Milk Alternatives: Effect of Protein Source and Homogenization Pressure. *Journal of the Science of Food and Agriculture*. 2021. DOI: 10.1002/jsfa.11230.

[9] AOCS. Taking the Cream Out of Ice Cream. *American Oil Chemists Society, AOCS* 2019.

[10] Marshall, R. T. Goff, H. D. Hartel, R. W. *2003. Ice Cream*. Springer US: Boston, MA.

[11] Arbuckle, W. S.; *Ice Cream*; Springer US: Boston, MA, 1986.

[12] El-Agamy, E. I. The Challenge of Cow Milk Protein Allergy. *Small Ruminant Research*. 2007 Mar, 68(1–2), 64–72. doi:10.1016/j.smallrumres.2006.09.016.

[13] Haas, R. Schneppa, A. Pichler, A. Meixner, O. Cow Milk versus Plant-Based Milk Substitutes: A Comparison of Product Image and Nutritional Structure of Consumption. *Sustainability*. 2019 Sep, 11(18), 5046. doi:10.3390/su11185046.

[14] Mäkinen, O. E.; Wanhalinna, V.; Zannini, E.; Arendt, E. K. Foods for Special Dietary Needs: Non-dairy Plant-based Milk Substitutes and Fermented Dairy-type Products. *Critical Reviews in Food Science and Nutrition*. 2016 Feb, 56(3), 339–349. doi:10.1080/10408398.2012.761950.

[15] Iriondo-Dehond, M.; Miguel, E. Del Castillo, M. D. Food Byproducts as Sustainable Ingredients for Innovative and Healthy Dairy Foods. *Nutrients*. 10.4, MDPI AG Oct. 01, 2018,1358.10.3390/nut10101358.

[16] Gemechu, F. G. Embracing Nutritional Qualities, Biological Activities and Technological Properties of Coffee Byproducts in Functional Food Formulation. *Trends Food Sci. Technol.* 2020, 104, 235–261. DOI: 10.1016/j.tifs.2020.08.005.

[17] Jardines, A. P.; Arjona-Román, J. L.; Severiano-Pérez, P.; Totosaus-Sánchez, A.; Fiszman, S.; Escalona-Buendia, H. B. Agave Fructans as Fat and Sugar Replacers in Ice Cream: Sensory, Thermal and Texture Properties. *Food Hydrocolloids*. Nov 2020, 108, 106032. DOI: 10.1016/j.foodhyd.2020.106032.

[18] Bisla, G.Verma, P.Sharma, S. Development of Ice Creams from Soybean Milk & Watermelon Seeds Milk and Evaluation of Their Acceptability and Nourishing Potential. *Pelagia Res. Libr. Adv. Appl. Sci. Res.*, vol. 2012, no. 1, pp. 371–376, 2012, Accessed, 2021www.pelagiaresearchlibrary.com

[19] Abdullah, M.; Saleem-ur-rehman, H. Z.; Saeed, H. M.; Kousar, S.; Shahid, M. Effect of Skim Milk in Soymilk Blend on the Quality of Ice Cream. *Pakistan Journal of Nutrition*. 2003 Aug, 2(5), 305–311. doi:10.3923/ pjn.2003.305.311.

[20] Akesowan, A. Influence of Soy Protein Isolate on Physical and Sensory Properties of Ice Cream. *Thai J. Agric. Sci* 2009, 42(1), 1–6.

[21] Small, E. Lupins - Benefit and Harm Potentials. *Biodiversity*. 2012, 13(1), 54–64. DOI: 10.1080/14888386.2012.658327.

[22] Bähr, M.; Fehner, A.; Hasenkopf, K.; Mittermaier, S.; Jahreis, G. Chemical Composition of Dehulled Seeds of Selected Lupin Cultivars in Comparison to Pea and Soya Bean. *LWT - Food Science and Technology*. 2014 Nov, 59 (1), 587–590. doi:10.1016/j.lwt.2014.05.026.

[23] Raikos, V.; Neacsu, M.; Russell, W.; Duthie, G. Comparative Study of the Functional Properties of Lupin, Green Pea, Fava Bean, Hemp, and Buckwheat Flours as Affected by pH. *Food Science & Nutrition*. 2014 Nov, 2(6), 802–810. doi:10.1002/fsn3.143.

[24] Thambiraj, S. R.; Reddy, N.; Phillips, M.; Koyyalamudi, S. R. Biological Activities and Characterization of Polysaccharides from the Three Australian Sweet Lupins. *International Journal of Food Properties*. 2019 Jan, 22 (1), 522–535. doi:10.1080/10942912.2019.1588298.

[25] Bhat, R.; Karim, A. A. Exploring the Nutritional Potential of Wild and Underutilized Legumes. *Compr. Rev. Food Sci. Food Saf.* 2009, 8(4), 305–331. DOI:10.1111/j.1541-4337.2009.00084.x.

[26] Chapleau, N.; De Lamballerie-Anton, M. Improvement of Emulsifying Properties of Lupin Proteins by High Pressure Induced Aggregation. *Food Hydrocolloids*. 2003 May, 17(3), 273–280. doi:10.1016/S0268-005X(02)00077-2.
[27] Maghamian, N.; Goli, M.; Najarian, A. Ultrasound-assisted Preparation of Double Nano-emulsions Loaded with Glycyrrhizic Acid in the Internal Aqueous Phase and Skim Milk as the External Aqueous Phase. LWT. Apr 2021, 141, 110850. DOI: 10.1016/J.LWT.2021.110850.

[28] Zaghian, N.; Goli, M. Optimization of the Production Conditions of Primary (W1/O) and Double (W1/O/W2) Nano-emulsions Containing Vitamin B12 in Skim Milk Using Ultrasound Wave by Response Surface Methodology. Journal of Food Measurement and Characterization 2020, 146, 3216–3226 10.1007/S11694-020-00567-1. Jul. 2020

[29] AOAC. Official Methods of Analysis of AOAC International, Maryland, USA, 2000.

[30] Clarke, C.; The Science of Ice Cream; Royal Society of Chemistry: Cambridge, 2007.

[31] Umelo, M. C.; Uzoukwu, A. E.; Odimegwu, E. N.; Agunwah, I.; Njoku, N.; Alagbaoso, S. Proximate, Physicochemical and Sensory Evaluation of Ice Cream from Blends of Cow Milk and Tigernut (Cyperus Esculentus) Milk. Int. J. Sci. Res. Innov. Technol 2014, 1(4), 63–76.

[32] “Banana Plant Extract Could Be Key to Creamier, Longer Lasting Ice Cream - American Chemical Society.” Accessed: Jan. 14, 2022. [Online]. Available: https://www.acs.org/content/acs/en/pressroom/newsreleases/2018/march/banana-plant-extract-could-be-key-to-creamier-longer-lasting-ice-cream.html.