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A novel functional reduced fat ice cream produced with pea protein isolate instead of milk powder

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Abstract

In this study, the possibilities of using pea protein isolate in the production of functional reduced fat ice cream, and vegetarian/vegan ice cream were investigated. For this purpose, six different ice creams were produced with different proportions of pea protein isolate (A: 0%, B: 6%, C: 12%, D: 25%, E: 100% pea protein isolate and milk fat (4%), F: 100% pea protein isolate and vegetable fat (4%)), and physical, chemical, textural, and sensory analysis of ice creams were carried out on the 1st, 30th, and 60th days of storage. Results showed that adding pea protein isolate as a substitute for milk powder improved the physical and textural properties of ice cream, but the addition of high amounts of pea protein isolates negatively affected the sensory properties, and was not suitable for vegan type ice cream production in terms of sensory properties.

Practical applications

Commonly consumed all over the world, ice cream provides important nutritional additions to our diet, including energy, calcium, protein, and other micronutrients. To increase the nutritional value of ice cream research has been conducted on the production of ice cream containing natural antioxidants, natural pigments, vitamins, low-fat and free from synthetic additives such as fruit and vegetables, probiotics, vegetable milk, and vegetable proteins. There is an increasing interest in vegetable proteins because of their health benefits. Less consumed by children, peas (*Pisum sativum*) have become a popular alternative protein source with their high protein content as well as their versatility as a sustainable, nutritious, and low-allergen food source. As far as is known, there is no study on ice cream production with pea protein isolate. In this study, new formulations were created to produce functional and vegetarian/vegan ice cream. By transferring these products to the industry, it will be possible to get a new product for the use of pea protein isolate and to increase the consumption of peas by children.

1 | INTRODUCTION

In recent years, because of the increasing demands for healthy foods, functional foods have gained popularity all over the World. Functional foods are not only delivered basic nutrients but also provide health benefits (Granato et al., 2020; Villava et al., 2017). Dairy products provide nutritionally important contributions to our diet, including energy, calcium, protein, and other micronutrients (Hassan & Barakat, 2018). Ice cream is the best-favored dairy product are liked by people of all age groups around the World, whereas the commercial ice cream available is generally poor in natural antioxidants like vitamin C, natural pigments, and polyphenols. To increase the nutritional value of ice cream in the last two decades, researches have been conducted on the production of ice cream containing natural antioxidants, natural pigments, vitamins, low-fat, and free from synthetic additives such as fruit and vegetables (Hassan & Barakat, 2018), probiotics (Aboulfazli et al., 2016), vegetable milk (Goral et al., 2018), and vegetable proteins (Al et al., 2020; Chen et al., 2019; Sivasankari et al., 2019; Yazdi et al., 2020).

Pea (*Pisum sativum*) has become a popular alternative protein source with its high protein content as well as versatility as a sustainable, nutritious, and low allergen food source. Pea protein is mainly composed of 7S/11S globulin (salt-soluble, 65% to 80% of total) and albumin 2S (water-soluble, 10% to 20%) protein classes, and contains high levels of lysine, used to balance its deficiency in cereal-based diets. Many studies suggested that pea protein (most times, pea protein hydrolysates and specific peptide fractions) has antioxidant, antihypertensive, anti-inflammatory, lowering cholesterol, and modulating intestinal bacteria activities (Ge et al., 2020; Liao et al., 2019).

Besides to its health benefits, the functional properties of pea protein also play a vital role in food processing. Here, the functionality of pea protein refers to all properties contributing to the structure and texture of food products, including its solubility, water holding capacity (WHC) and oil-holding capacity (OHC), emulsifying properties, foaming properties, and gelling properties. Thus expand its application in food formulations (Ge et al., 2020).

In this study, it was aimed to investigate the production of a new functional ice cream using pea protein isolate, which is a new alternative to animal proteins, with health benefits and functional properties. Also, in this study, it was investigated whether vegetarian/vegan ice cream could be produced with a pea protein formulation containing high lysine and vegetable oil. For this purpose, six different ice creams containing pea protein isolate in different proportions were produced and stored for 60 days, physical, chemical, textural, and sensory properties at 30th and 60th days determined.

2 | MATERIALS AND METHODS

2.1 | Materials

Milk powder (Pınar Dairy A.Ş., İzmir), cream (35% fat) (Pınar Dairy A.Ş., İzmir), commercial granulated sugar, vanillin, stabilizer (Tito) consisting of a mixture of sodium alginate (E 401), carrageenan (E 407); guar gum (E 412), and carob gum (E 410), emulsifier consisting of lecithin (Boll food, Emulsified Paste), hydrogenated palm kernel oil (Vita, Turkey), and pea protein isolate (Alfasol AS, Turkey) were used as materials for ice cream production. The composition of the pea protein isolate declared by the company is 85% protein, 0% carbohydrate, 7% fiber, and 5% fat, while the composition of milk powder is 36% protein, 52% carbohydrate, and 1.25% fat.

All other reagents used were of analytical grade. All other reagents used were of analytical grade Merck or/and Sigma, Turkey).

2.2 | Ice cream production

In preliminary trials, it was determined that the upper limit of pea protein isolate addition that can be considered as sensory was 25%, thus ice creams were formulated to contain 0% (control), 6%, 12%, and 25% pea protein isolate. An ice cream containing 100% pea protein isolate was produced as a positive control. In addition, one more ice cream, were prepared using 100% pea protein isolate and completely palm oil following the vegan diet.

Ice cream mixes have been formulated as fat-free dry matter content 11% (A: 100% milk powder + 0% pea protein isolate; B: 94% milk powder + 6% pea protein isolate; C: 88% milk powder + 12% pea protein isolate; D: 75% milk powder + 25% pea protein isolate; E: 0% milk powder + 100% pea protein isolate, F: 0% milk powder + 100% pea protein isolate) fat content 4% (A, B, C, D, and E: 4% milk cream, F: 4% hydrogenated palm kernel oil), sugar content 18%, stabilizer content 0.8%, emulsifier content 0.2%, and vanillin content 0.2%.

Ice cream mixes were prepared in the Milk and Dairy Products Research Laboratory of the Food Engineering Department of Harran University. Prepared mixes were pasteurized at 80°C for 1 min, then homogenized with the help of an electric mixer, and allowed to cool to 4°C. At this temperature, they were kept for 18–24 hr. Then the mixes were frozen in a batch-type ice cream machine (Uğur Ltd., Turkey) for 15 min, and packed in 100 ml plastic containers. The temperature of ice cream packaged ice creams were approximate −8 ± 2°C, they were hardened at −25°C and stored at this temperature for 60 days. Physical, chemical, textural, and sensory analysis of ice creams were performed on the 1st, 30th, and 60th days of storage. The experiment was conducted in duplicate.

2.3 | Physical measurements

The overrun of the final product was determined using the formula (Akin et al., 2007):

$$\text{Overrun} = (\text{Weight of unit mix - weight of an equal volume of ice cream}) / \text{Weight of equal volume of ice cream} \times 100$$

First dripping and complete melting times were measured according to Guven and Karaca (2002). Twenty five grams of tempered samples were left to melt (at room temperature, 20°C) on a 0.2 cm wire mesh screen above a beaker. First dripping and complete melting times of samples were determined as seconds. The viscosities of the ice creams were determined at 4°C using a digital Brookfield Viscometer, Model DV-II (Brookfield Engineering Laboratories, Stoughton, MA, USA) (Akin et al., 2007). The melting rate was determined according to Cottrell et al. (1979). The ice creams were taken from the plastic container they were in, and their weight was determined (25 g) and placed on beakers with a 2.5 mm mesh wire strainer. The melted fractions accumulated under the beakers, and then at 15, 30, 45, 60, 75, 90, and 105 min.

The weight of the solutes collected in the beaker was measured. The results were calculated by the formula below and expressed in%:

$$\text{Melting rate}\,(\%) = (\text{Weight of Melted Part}/\text{Weight of Ice Cream}) \times 100$$

2.4 | Chemical analysis

The pH of the ice cream was measured using a digital pH meter and titratable acidity was measured by titrating 10 g of sample with 0.1 N NaOH using phenolphthalein as an indicator (TSE, 1994). The dry matters of ice cream were determined by drying samples at 100 ± 1°C for 3.5 hr using an air oven (TSE, 1994). The fat content of milk ice cream was determined by the Gerber method (TSE, 1994).

2.5 | Color measurements

A reflectance colourimeter (Colour Quest XE, USA) was used to determine Hunter *L*, *a* and *b* color parameters of the ice cream samples. The source of light and the observation angle are D65 and 10°.

2.6 | Texture measurements

The textural properties of ice creams were evaluated by the textural profile analysis (TPA) method (Sun et al., 2015). TPA was performed on ice cream samples using a triple compression test (TA-XT2i Texture Analyzer; Stable MicroSystems, NY, USA). For TPA, 50 ± 5 g sample was extended on a flat surface and carefully rolled to a thickness of about 20 mm. Conditions were as follows: a cylindrical probe (5 mm in diameter) was inserted to a depth of 20% of their original height into the sample at a speed of 1 mm⁄s in a reciprocating motion to give a two-bite TPA curve, with an interval of 75 s between compressions. The following parameters were evaluated: hardness, adhesiveness, cohesiveness, springiness, and gumminess.

2.7 | Sensory assessment

The samples were subjected to sensory evaluation by untrained ten panellists using 10 points hedonic scale to evaluate coldness, firmness, viscosity, smoothness, color, and appearance, mouth-coating, flavor and taste, and general acceptability (1 = strongly unacceptable, 10 = very good) as described by Aime et al. (2001). Panellists who were trained in other studies were selected from the university student population and consisted of ten master students, eight females and two males, all between the ages of 20 and 24. Seven 30 min training sessions were held over 1 month. The first training session was used to introduce panellists to the prepared ballot, spooning technique and the amount of ice cream to use for assessment. The next five sessions it was taught (a) introduce a new attribute and definition (b) discuss and practice the new attribute on the reference sample as well as two or three coded samples, and (c) practice and review the attributes learned during a previous training session. During the final session, all attributes were evaluated for six coded samples.

2.8 | Statistical analysis

Statistical analysis of data via one-way analysis of variance (ANOVA) was performed to check the significance of differences at $p < .05$ using SPSS Version 21.0 (SPSS Inc. Chicago, IL, USA). Statistically different groups were determined by the TUKEY test (Bek & Efe., 1995).

3 | RESULTS AND DISCUSSION

3.1 | Chemical and physical characteristics

The gross composition of ice creams was determined was given in Table 1. The addition of pea protein isolate instead of milk powder significantly affected pH, titratable acidity, and protein contents of ice creams. While pH values of samples E (100% pea protein isolate) and *F* (100% pea protein isolate) are higher than the other samples, the titratable acidity of them was found lower the other samples because of the high pH value of pea protein isolate. Sivasankari et al. (2019) reported that, as the proportion of chickpea and pea protein increased, the pH values of ice creams increased. A positive correlation was found between the pea protein isolate and the

TABLE 1 Gross composition of ice creams

Ice creams	pH	Titratable acidity (%)	Dry matter (%)	Protein (%)	Fat (%)
A	6.57 ± 0.01^{a}	0.24 ± 0.01^{c}	35.58 ± 0.07^{d}	3.99 ± 0.03^{a}	4.13 ± 0.03^{a}
B	6.57 ± 0.02^{a}	0.24 ± 0.02^{bc}	35.07 ± 0.08^{a}	4.29 ± 0.06^{b}	4.13 ± 0.03^{a}
C	6.65 ± 0.02^{a}	0.21 ± 0.01^{abc}	35.39 ± 0.06^{c}	4.58 ± 0.04^{c}	4.18 ± 0.03^{a}
D	6.69 ± 0.00^{a}	0.20 ± 0.01^{a}	35.22 ± 0.04^{b}	5.04 ± 0.13^{d}	4.13 ± 0.03^{a}
E	6.94 ± 0.10^{b1}	0.20 ± 0.01^{ab1}	35.25 ± 0.02^{bc1}	9.61 ± 0.04^{e1}	4.18 ± 0.03^{a1}
F	7.00 ± 0.05^{b1}	0.19 ± 0.01^{a1}	35.29 ± 0.02^{bc1}	9.53 ± 0.09^{e1}	4.18 ± 0.03^{a1}

Note: A:0% (control), B: 6%, C: 12%, D: 25%; E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil. Data shown with different lowercase letters and with different numbers are statistically different from each other according to the ratio of pea protein isolate and fat type, respectively (α: 0.05).

protein contents of the samples. The protein contents of ice creams (samples E and F) produced entirely with pea protein isolate were found to be almost three times as high as the control sample (A). This result is related to the protein contents of pea protein isolate and milk powder. When the compositions of milk powder and pea protein isolate given in the material and method section are examined, it is seen that pea protein contains almost 2.5 times the protein of milk powder. Sivasankari et al. (2019) also found that depending on the rate of chickpea protein, the protein values of ice creams are 2.5–3 times higher than the control sample. Fat type (milk fat or vegetable oil) did not change the chemical composition of the experimental ice creams ($p > .05$).

Changes in the physical properties of ice creams during storage are given in Table 2. The effects of pea protein isolate addition instead of milk powder were found to be significant on the viscosity, overrun, first dripping and complete dripping times of ice creams ($p < .05$). It was determined that as the rate of pea protein isolate added to the mixes increased, the mix viscosity increased. This result can be attributed to the fact that the gland and its proteins form a more stable gel matrix due to their high-water retention and water-binding property (Boye et al., 2010). Similar findings were obtained in the viscosity of ice creams in many studies on ice cream production with the addition of vegetable protein or milk with high protein content (Ahanian et al., 2014; Akesowan, 2009; Gracas-Pereira et al., 2011; Roccia et al., 2009). On the other hand, fat type did not affect the viscosity of ice creams ($p >.05$). The viscosity of vegan type ice cream was found to be higher than control, but no difference was determined between the viscosity of E (100% pea protein isolate) and *F* (100% pea protein isolate) samples.

Overrun values of ice creams changed between 5.51 ± 0.25% and 33.15 ± 0.32%. A negative correlation was found between the amount of pea protein isolate and the overrun values of ice creams, as the very high viscosity gel matrix may negatively affect the air incorporation during the freezing process (Sivasankari et al., 2019). Igutti et al. (2011) determined strong gel matrix resulted in the lower overrun values in ice creams with green coconut pulp. Gracas Pereira et al. (2011) and Badıllı (2020) reported that as soy protein extract and chickpea flour increased due to the increased viscosity, the overrun values of ice creams decreased, respectively. Gabbi et al. (2018) and Yazdi et al. (2020) also reported that the addition of ginger, banana flour, and microencapsulated pistachio peel extract cause decreasing the overrun of ice cream. While there were higher overrun values in vegan-type ice cream compared to control, there was no difference between E (100% pea protein isolate) and *F* (100% pea protein isolate) samples containing different fat types.

Whilst the addition of pea protein isolate prolonged the first dripping and complete melting time, there was no melting in the ice creams produced with completely pea protein isolate (samples E and F). The addition of pea protein isolate leads to a rise in flow resistance of ice cream due to increased viscosity and it was probably reduced melting of ice cream. Sivasankari et al. (2019) also reported that due to the liquid binding property of pulse protein to form a

TABLE 2 Changes in physical properties of ice creams during storage

Ice creams	Storage period (day)	Viscosity (cP)	Overrun (%)	First dripping time (s)	Complete melting time (s)
A	1.	$2,314 \pm 175^{a1}$	33.15 ± 0.32^{d2}	560 ± 40^{b1}	$3,325 \pm 25^{b1}$
	30	$2,634 \pm 18^{a1}$	32.93 ± 0.29^{d12}	$1,200 \pm 30^{b1}$	$3,875 \pm 25^{b1}$
	60	$3,338 \pm 94^{a1}$	31.62 ± 0.25^{d1}	$1,020 \pm 60^{b1}$	$3,510 \pm 50^{b1}$
B	1.	$2,738 \pm 62^{a1}$	32.55 ± 0.45^{d2}	935 ± 5^{bc1}	$4,175 \pm 25^{c1}$
	30	$3,213 \pm 114^{a1}$	32.14 ± 0.27^{d12}	$1,275 \pm 25^{bc1}$	$4,449 \pm 29^{c1}$
	60	$3,957 \pm 120^{a1}$	31.03 ± 0.18^{d1}	$1,075 \pm 55^{bc1}$	$4,255 \pm 25^{c1}$
C	1.	$4,079 \pm 20^{b1}$	27.92 ± 0.15^{c2}	970 ± 10^{c1}	$4,628 \pm 27.5^{d1}$
	30	$4,713 \pm 60^{b1}$	27.22 ± 0.32^{c12}	$1,245 \pm 45^{c1}$	$4,847 \pm 7.5^{d1}$
	60	$5,219 \pm 61^{b1}$	26.90 ± 0.16^{c1}	$1,280 \pm 20^{c1}$	$4,735 \pm 25^{d1}$
D	1.	$5,586 \pm 220^{c1}$	22.40 ± 0.30^{b2}	$1,195 \pm 35^{d1}$	$5,720 \pm 30^{e1}$
	30	$6,121 \pm 132^{c1}$	21.99 ± 0.21^{b12}	1575 ± 45^{d1}	$6,042 \pm 31.5^{e1}$
	60	$6,521 \pm 252^{c1}$	21.03 ± 0.31^{b1}	1525 ± 35^{d1}	$5,775 \pm 25^{e1}$
E	1.	$10,397 \pm 69^{d1A}$	16.79 ± 0.26^{a2A}	–	–
	30	$11,782 \pm 93^{d1A}$	16.07 ± 0.32^{a12A}	–	–
	60	$12,445 \pm 67^{d1A}$	15.88 ± 0.17^{a1A}	–	–
F	1.	$10,322 \pm 56^{d1A}$	16.06 ± 0.35^{a2A}	–	–
	30	$11,129 \pm 95^{d1A}$	15.73 ± 0.15^{a12A}	–	–
	60	$12,027 \pm 30^{d1A}$	15.51 ± 0.25^{a1A}	–	–

Note: A:0% (control), B: 6%, C: 12%, D: 25%; E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil. Data shown with different lowercase letters, different capital letters and with different numbers are statistically different from each other according to the ratio of pea protein isolate, fat type, and the storage period, respectively (α: 0.05).

stable gel network, which leads to immobilization of the water molecules to move freely among other molecules of the mix lead to reduce melting of ice cream. Similar results have been found by Gabbi et al. (2018), Yazdi et al. (2020), and Badıllı (2020). In addition, it is estimated that the fibres (7%) in the pea protein isolate will bind water and slow their melting.

Whereas overrun values of ice creams declined, viscosity, first dripping, and complete melting time rose during the storage period ($p < .05$). Ahanian et al. (2014) reported that soy proteins have high water absorption, and this issue increases hydration of mix during aging, on the other hand that soybean carbohydrates are mainly polysaccharides, and these materials also have the power to format gels, thus increase substitution levels of soy milk can increase the viscosity of the mixture. It is predicted that pea proteins act similarly, thus increasing their viscosity during storage. This situation may also lead to a longer melting time during storage. Declining in overrun values of ice cream during storage has to be related to the viscosity increase in the samples. Graças-Pereira et al. (2011), Sivasankari et al. (2019), Aloğlu (2019), and Badıllı (2020) reported that increasing viscosity reduces the overrun of ice creams.

Melting rates of the ice creams at the end of 15, 30, 45, 60, 75, 90, and 105 min are given in Figure 1. Pea protein isolate addition significantly affected the melting behavior of ice creams ($p < .05$). While melting occurred only in the control (A) sample in the first 15 min, it also started in the samples containing 6% (B), 12% (C), and %25 (D) pea protein isolate in the 30th minute. When the melting rates of the samples were compared for 105 min, it was determined that there is a negative correlation (−0.207) between the melting rate and the

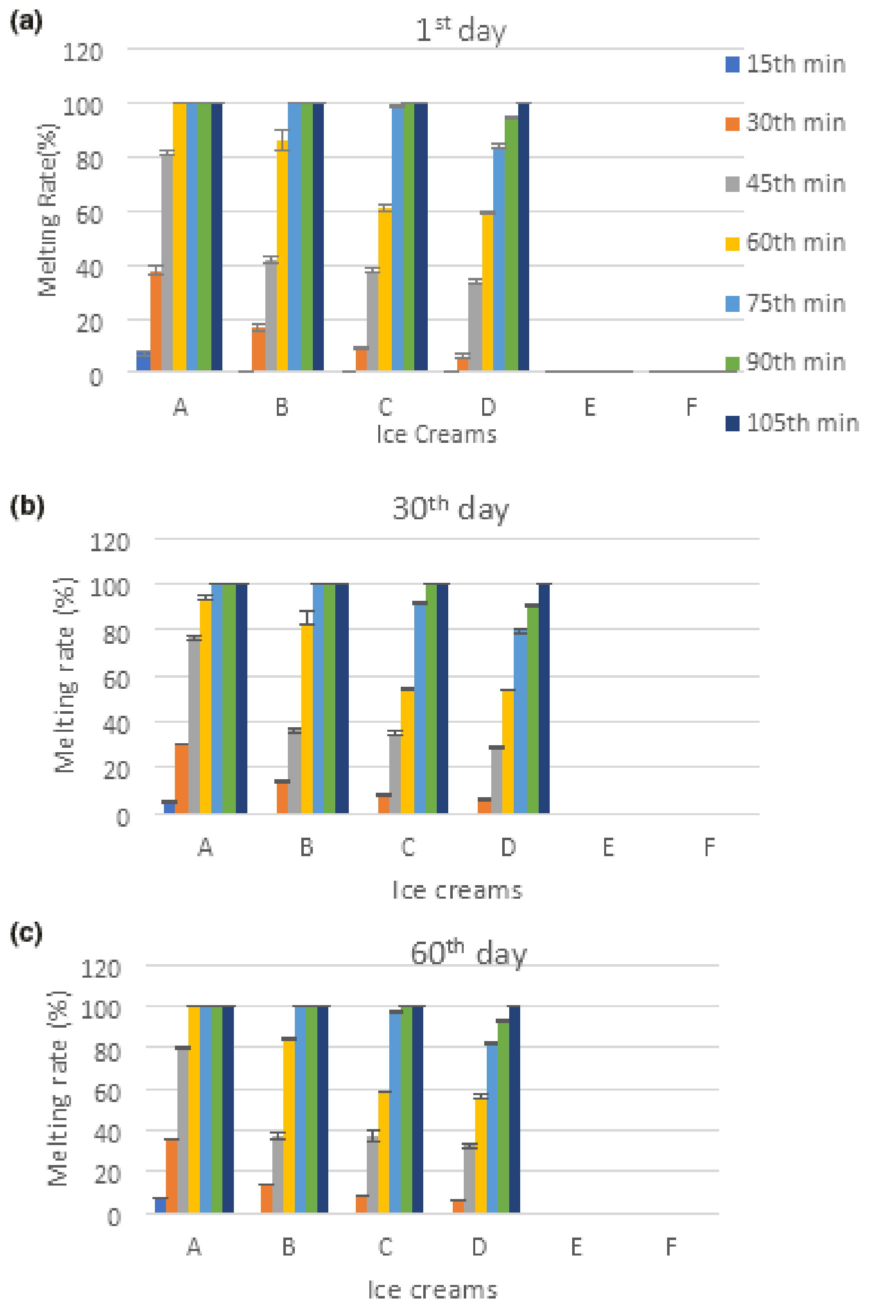

FIGURE 1 Melting rate (%) of ice creams (a) 1st day, (b) 30th day, (c) 60th day (A:0% (control), B: 6%, C: 12%, D: 25%, E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil)

amount of pea protein isolate. This result may be associated with increasing the viscosity of ice creams and also binding water due to the high fibres and protein content of pea protein isolate. Goff and Sahagian (1996) suggested that the addition of polysaccharides or hydrocolloid to ice cream not only increases the viscosity but also increases the melting resistance. Akin et al. (2007) reported that the addition of inulin increases the viscosity by binding the free water in ice creams and slows the melting. Muse and Hartel (2004) reported that ice creams with high consistency coefficients have a greater resistance to flow and thus melted slower. E and F samples containing 100% pea protein isolate no melting observed during the analysis period. In these samples melting was seen, but there was no passage under the strainer due to prevent the free movement of water in the matrix which contains very high protein and fiber. These results also may be related to overrun values of ice cream. Hassan and Barakat (2018) reported that a compact structure occurred in ice creams produced with high amounts of pumpkin fibre which prevents air from entering the ice cream matrix and thus, cause high melting resistance. During the storage period, the melting rates of ice creams first decreased and then increased ($p < .05$). However, it was found that the melting rate of ice creams, in general, decreased at the end of storage compared to the first day. This result can attribute to an increase in viscosity of the samples during low-temperature storage and also to the formation of new ice crystals due to temperature fluctuations during storage.

3.2 | Color measurement

*L**, *a**, and *b** values of ice creams varied between 68.00 ± 0.785 and 82.41 ± 0.16, 0.27 ± 0.02, 3.70 ± 0.16, and 10.84 ± 0.13, 18.71 ± 0.085, respectively (Figure 2). While the lighter color value was determined in the A samples, the darker color values were determined in the samples containing pea protein isolate due to the color of the isolate and the Maillard reaction that occurred during the heat treatment. Similar results obtained by Akesowan (2009) in ice cream with soybean protein isolate. *a** and *b** values of the samples increased with the increase of pea protein isolate due to its greenish brown color ($p < .05$). Sivasankari et al. (2019) reported that with the increase in pulses protein concentration, the *a** and *b** values of ice creams increased. The vegan ice cream color was found darker, greener, and redder than the control. There was no difference between the colors of the E and F samples containing 100% pea protein isolate depending on the fat type ($p < .05$). The storage period also did not affect the color of ice creams.

3.3 | Textural properties

The addition of pea protein isolate improved the textural properties of ice creams Table 3. As the pea protein isolate increased, the hardness, adhesiveness, springiness, cohesiveness, and gumminess values of ice creams increased due to its function as a stabilizer ($p <$

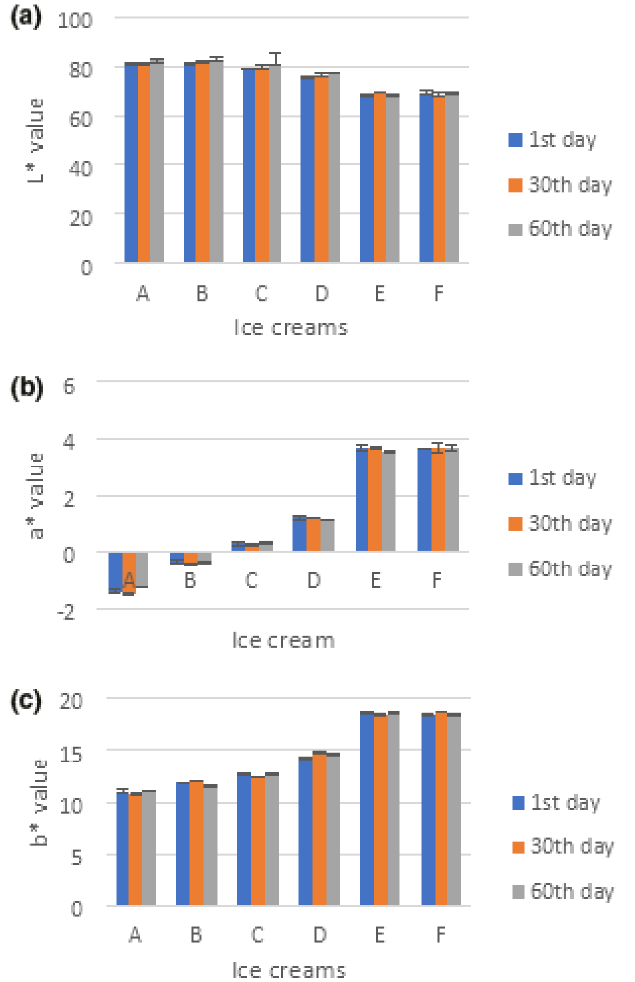

FIGURE 2 Colour value of ice creams (a) *L** value, (b) *a** value, (c) *b** value (A:0% (control), B: 6%, C: 12%, D: 25%, E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil)

.05). As known hardness value depends on the overrun value of ice cream. Wilbey et al. (1998) reported that less overrun resulted in harder texture. Akesowan (2009) and Badıllı (2020) also reported that the addition of soy protein and chickpea flour increased the hardness values of ice cream. Adhesiveness is correlated with hardness, thus, a decrease in adhesive force will be observed as hardness decreases (Sun et al., 2015). Consequently, ice creams containing all pea protein isolate had the highest adhesiveness value. Since hard products are generally less elastic, the springiness values of ice creams increase with pea protein isolate. Sun et al. (2015) reported that as the soy protein isolate rate increased, the elasticity values of the samples increased. It was determined that the cohesiveness values increased due to the formation of a firmer three-dimensional protein-fat matrix in ice creams depending on the pea protein isolate ratio. In addition, it is thought that the fibres in pea protein isolate bind water and form a more viscous and tight structure, thus causing an increase in internal adhesion values. Sun et al. (2015) and Badıllı (2020) found similar results in ice creams with soy protein isolate and chickpea flour, respectively. Gumminess (hardness x cohesiveness) is

TABLE 3 Textural properties of ice creams

Ice creams	Storage period (day)	Hardness (*N*)	Adhesiveness (mj)	Elasticity (mm)	Cohesiveness	Gumminess (*N*)
A	1.	$378{\pm}13^{a1}$	$-104{\pm}7^{c1}$	0.88 ± 0.01^{a1}	0.13 ± 0.02^{a1}	49.43 ± 9.31^{a1}
	30	520 ± 22^{a1}	-124 ± 8^{c1}	0.94 ± 0.01^{a12}	0.18 ± 0.01^{a2}	96.01 ± 7.02^{a12}
	60	707 ± 13^{a1}	-268 ± 3^{c1}	0.95 ± 0.00^{a2}	0.24 ± 0.01^{a2}	171.87 ± 12.48^{a2}
B	1.	495 ± 16^{a1}	-216.14 ± 6.40^{c1}	0.95 ± 0.01^{b1}	0.18 ± 0.02^{ab1}	86.60 ± 8.74^{ab1}
	30	793 ± 54^{a1}	-245.32 ± 13.21^{c1}	0.96 ± 0.01^{b12}	0.22 ± 0.00^{ab2}	173.61 ± 8.82^{ab12}
	60	990 ± 18^{a1}	-316.01 ± 11.90^{c1}	0.97 ± 0.01^{b2}	0.24 ± 0.01^{ab2}	239.75 ± 13.36^{ab2}
C	1.	902 ± 38^{b1}	-282.29 ± 12.10^{b1}	0.95 ± 0.01^{b1}	0.22 ± 0.01^{bc1}	$201.99 \pm 14.39b^{1}$
	30	$1,145 \pm 54^{b1}$	-312.52 ± 6.10^{b1}	0.96 ± 0.00^{b12}	0.25 ± 0.01^{bc2}	292.26 ± 28.01^{b12}
	60	$1,433 \pm 27^{b1}$	-626.90 ± 21.11^{b1}	0.98 ± 0.00^{b2}	0.27 ± 0.01^{bc2}	389.44 ± 18.11^{b2}
D	1.	$1,338 \pm 118^{c1}$	-435.90 ± 1.92^{b1}	0.96 ± 0.01^{b1}	0.25 ± 0.00^{cd1}	332.26 ± 24.57^{c1}
	30	2099 ± 36^{c1}	-481.98 ± 3.57^{b1}	0.97 ± 0.00^{b12}	0.29 ± 0.00^{cd2}	598.30 ± 1.76^{c12}
	60	$2,403 \pm 45^{c1}$	-835.18 ± 25.89^{b1}	0.97 ± 0.01^{b2}	0.29 ± 0.01^{cd2}	623.20 ± 23.40^{c2}
E	1.	$2,467 \pm 88^{d1A}$	-2339.45 ± 49.32^{a1A}	0.97 ± 0.00^{d1A}	0.25 ± 0.00^{cd1A}	891.53 ± 10.83^{d1A}
	30	$3,085 \pm 37^{d1A}$	-2494.53 ± 23.20^{a1A}	0.98 ± 0.00^{d12A}	0.29 ± 0.01^{cd2A}	$1,108.47 \pm 7.34^{d12A}$
	60	$3,391 \pm 85^{d1A}$	-2873.92 ± 5.24^{a1A}	1.00 ± 0.00^{d2A}	0.33 ± 0.01^{cd2A}	699.24 ± 1.44^{d2A}
F	1.	$2,435 \pm 88^{e1A}$	-2292.53 ± 57.60^{a1A}	1.00 ± 0.00^{d1A}	0.26 ± 0.00^{d1A}	635.19 ± 13.32^{d1A}
	30	$2,863 \pm 44^{e1A}$	-2627.47 ± 24.52^{a1A}	0.99 ± 0.01^{d12A}	0.29 ± 0.01^{d2A}	830.05 ± 4.49^{d12A}
	60	$3,291 \pm 88^{e1A}$	-3001.56 ± 30.81^{a1A}	1.00 ± 0.00^{d2A}	0.34 ± 0.01^{d2A}	$1,106.79 \pm 1.76^{d2A}$

Note: A:0% (control), B: 6%, C: 12%, D: 25%; E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil. Data shown with different lowercase letters, different capital letters and with different numbers are statistically different from each other according to the ratio of pea protein isolate, fat type, and the storage period, respectively (α: 0.05).

derived as a secondary parameter. Therefore, the gumminess value of ice creams containing entirely pea protein isolate was the highest.

Due to the reasons explained above, it was determined that vegan type ice creams had higher hardness, adhesiveness, springiness, cohesiveness, and gumminess values compared to the control. It was determined that fat type did not make a statistical difference in the textural properties of ice creams ($p > .05$). The hardness, adhesiveness, springiness, cohesiveness, and gumminess values of ice creams increased during the storage period. This may be related to the increase in viscosity which causes the hardness of ice creams stored at low temperature to increase.

3.4 | Sensory evaluations

The addition of pea protein isolate negatively affected sensory characteristics (Figure 3) of ice creams ($p < .05$). As the pea protein isolate increased, the coldness, smoothness, color, and appearance, taste and odor and general acceptability scores of the ice creams declined, while the firmness, viscosity, and mouth-coating scores rose. As melting occurs within the mouth, larger ice particles are momentarily left behind creating the distinct sensation of coldness (Aime et al., 2001). Pea protein isolate containing water-binding protein and fibres could impair the formation of large ice

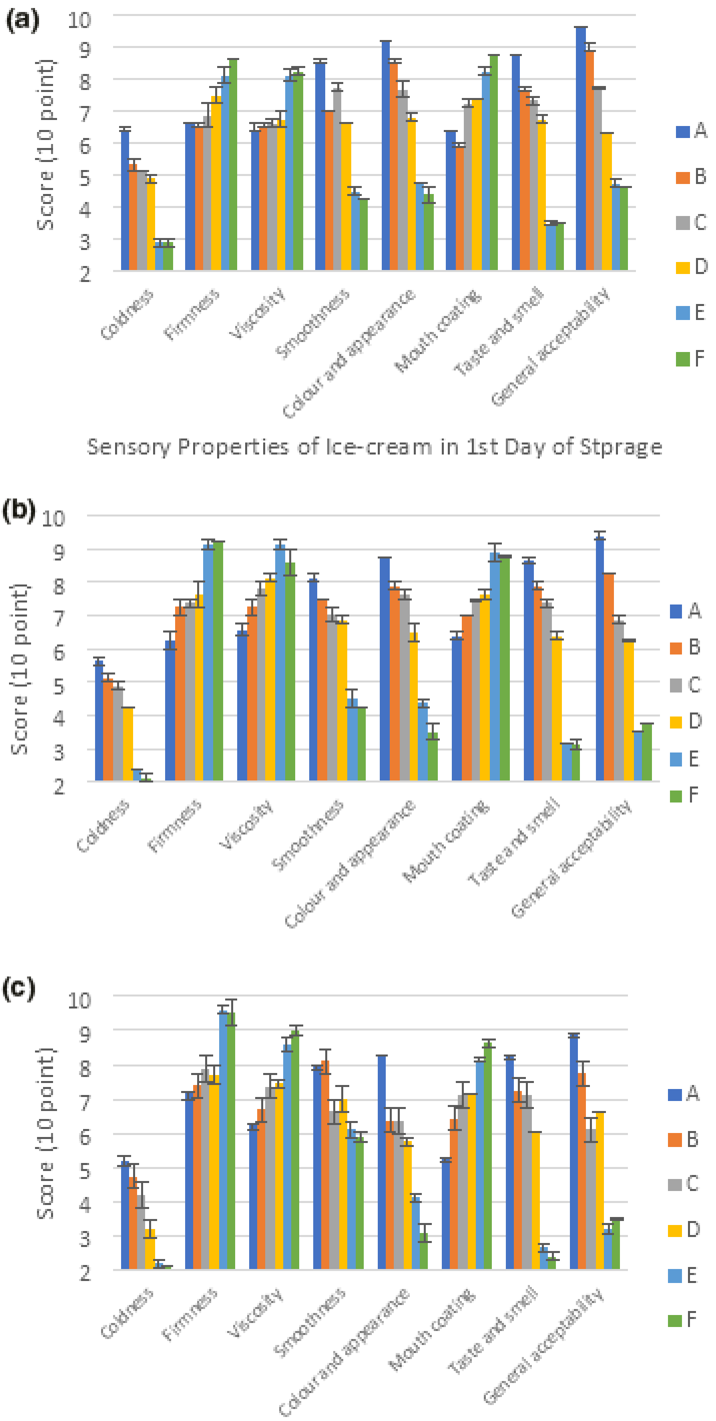

FIGURE 3 Sensory properties of ice creams (a) 1st day of storage, (b) 30th day of storage, (c) 60th day of storage (A:0% (control), B: 6%, C: 12%, D: 25%, E: 100% pea protein isolate and milk fat, F: 100% pea protein isolate and hydrogenated palm oil)

crystals, and thus limit the perception of coldness. Badıllı (2020) has reported similar results in ice creams fortified with chickpea flour.

As known firmness is related to the structure of ice cream. The air cells in the ice cream structure formed depending on the overrun rate soften it. When the overrun decrease, the resistance of the ice cream to deformation through the tongue will increase during sensory testing. Therefore, the firmness scores of the ice cream increased with increasing pea protein isolate. These findings are parallelism with instrumental hardness values of ice cream. Liu et al. (2018) reported that the amount of soy protein isolate significantly increased their firmness scores.

Viscosity indicates the melting state of ice cream in a person's mouth. As the pea protein isolate increased, the melting time of ice creams in the mouth was prolonged due to the increase in protein content. In addition, fibers in pea protein isolate can also increase viscosity by binding water. There was also a correlation (0.785) between sensory and instrumental viscosity of the samples. Smoothness means the sample has a smooth and uniform spread onto the palate and no coarse or rough texture is detectable (Aime et al., 2001). A negative correlation (−0.428) has been detected between pea protein isolate and smoothness scores of the samples. This may be due to the different proteins in pea protein isolate and milk powder. Ahanian et al. (2014) reported that the ice cream containing 100% soy milk had a burly and coarse texture due to a lack of casein protein. It is predicted that pea protein isolate containing proteins and fibres creates a coarse texture and therefore cause a decrease in the smoothness scores of ice creams.

The color and appearance scores of ice creams were evaluated by panellists from dull to bright and from light to dark. Pea protein isolate caused ice creams to have a color ranging from light green to dark khaki or light brown, and therefore ice creams containing pea protein isolate scored lower than the control sample.

One of the most effective sensory parameters in accepting a product by consumers is the taste and smell of the product. Smell consists of concepts such as the perception of volatile compounds that come out of a food substance taken into the mouth by smelling, taste-perception of soluble substances in the mouth, and the sensation of bitter and sourness perceived by stimulating the nerves in the mouth and nasal cavity. It was determined that the peculiar legume taste and smell of peas changed the natural taste and odor of ice creams and therefore, as the rate of pea protein isolate added to ice creams increased, the samples were not liked by the panellists. It was determined that this taste and odor were not evident in the samples with low levels of pea protein isolate and the taste and odor scores of these samples containing 6% (B), and 12% (C) were close to the control sample. However, the taste and odor scores of the ice creams produced entirely with pea protein (E and F samples) were found to be significantly lower than the control.

Mouth coating refers to the amount of films remaining in a person's mouth after swallowing. Aime et al. (2001) reported that the mouth coating is related to the fat content of the ice creams, and as the fat content increases, the mouth coating increases. In addition, water-binding agents that act as fat replacements also make the mouth feel more intense (Aime et al., 2001; Specter & Setser, 1994). Since the fibres and proteins in the pea protein isolate bind water and act as a fat substitute and slow the melting of ice cream by binding water, the higher the rate of pea protein isolate, the more intense the mouth coating of ice creams is felt.

There is a negative correlation (−0.472) between pea protein isolate ratio and general acceptability scores of ice creams. Whilst the general acceptability score of the B sample containing a small amount of pea protein (6%) isolate was found close to the control (A), it was found that the acceptability of the samples decreased as the ratio increased. The acceptability of samples produced entirely with pea protein isolate was very low compared to the control. This result can be attributed to the specific aroma of the pea protein. Pea protein isolate contains over 80% protein and is of great interest in the food industry due to its nutritional value. However, to obtain the protein isolate, peas undergo transformations involving a series of pH and temperature processes that promote non-enzymatic reactions such as Maillard (Boye et al., 2010). During pea protein extraction and processing, the concentration of endogenous fragrance active compounds has been reported to be significantly reduced; however, other fragrance compounds such as (E) -2-octenal, (E, E) -3,5-octadien-2-one and 4-ethylbenzaldehyde resulting from the Maillard reaction and lipid degradation an increase in concentration has been reported (Azarnia et al., 2011; Murat et al., 2013; Trikusuma et al., 2020). It is estimated that these aroma components contained in pea protein isolate negatively affect the general acceptability of ice creams. Similar results were reported by Graças Pereira et al. (2011), Ahanian et al. (2014) and Badıllı (2020).

When all sensory parameters of vegan type ice creams (F) were compared with ice creams produced entirely from pea protein isolate (E), it was observed that there was no significant difference between them depending on the fat type ($p > .05$). All sensory scores declined during storage, except for the firmness and viscosity of the ice cream ($p < .05$).

4 | CONCLUSION

Results showed that adding pea protein isolate as a substitute for milk powder in the production of ice cream with reduced fat content improved the physical and textural properties of ice cream, but the addition of high amounts of pea protein isolate negatively affected the sensory properties and pea protein isolate has not been suitable for vegan type ice cream production in terms of sensory properties. However, it has been concluded that adding 6% and 12% pea protein isolate instead of milk powder in ice cream production with reduced fat content may have an important application potential in developing a functional new product.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

AUTHOR CONTRIBUTIONS

Conceptualization; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Software; Supervision; Validation; Visualization; Writing-original draft; Writing-review & editing: Mutlu Buket Akin. *Conceptualization; Formal analysis; Investigation; Methodology; Resources; Software; Visualization; Writing-original draft; Writing-review & editing*: Firdevs Avkan. *Formal analysis; Investigation; Methodology; Resources; Software; Validation; Writing-original draft; Writing-review & editing*: Musa Serdar Akin.

ETHICAL APPROVAL

Ethical Review: This study does not involve any human or animal testing.

DATA AVAILABILITY STATEMENT

Research data are not shared.

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