Journal Pre-proof

Inulin as a fat replacer in pea protein vegan ice cream and its influence on textural properties and sensory attributes

Vikram Reddy Narala , Ivars Orlovs , Madara Asnate Jugbarde , Markus Masin

PII: S2772-5022(22)00026-9
DOI: https://doi.org/10.1016/j.afres.2022.100066
Reference: AFRES 100066

To appear in: *Applied Food Research*

Received date: 22 December 2021
Revised date: 10 February 2022
Accepted date: 21 February 2022

Please cite this article as: Vikram Reddy Narala , Ivars Orlovs , Madara Asnate Jugbarde , Markus Masin , Inulin as a fat replacer in pea protein vegan ice cream and its influence on textural properties and sensory attributes, *Applied Food Research* (2022), doi: https://doi.org/10.1016/j.afres.2022.100066

Highlights

- Developing a low-fat vegan pea protein ice cream is a functional alternative to dairy ice cream
- Increase in inulin content lower the hardness of pea protein ice cream
- Inulin influence the melting properties of pea protein ice cream
- 2 to 4% of inulin addition as a fat replacer improves overrun of pea protein ice cream

Inulin as a fat replacer in pea protein vegan ice cream and its influence on textural properties and sensory attributes.

Vikram Reddy Narala[a,b*], Ivars Orlovs[b], Madara Asnate Jugbarde[a], Markus Masin[b]

[a]Nature Foods Ltd, Ģertrūdes iela 53 - 7, LV-1011, Rīga.

[b]Medical Institute for Nutrition Science and Technology, Uriekstes iela 1, Riga, LV-1005, Latvia.

[*]Author for correspondences: Email: vikramreddynarala@gmail.com (N. Vikram Reddy); Mailing Adress: Uriekstes iela 1, Riga, LV-1005, Latvia.

Abstract

The aim of the current study was to investigate the inulin feasibility as a fat replacer in developing the low-fat pea protein vegan ice cream with prebiotic properties. So, the inulin was added at 2, 4, 6, and 8 % to pea protein ice cream to replace the rapeseed oil and the melting behavior, hardness, adhesiveness and sensory attributes were compared with inulin-free pea protein ice cream. The results revealed that increased inulin content in the formulations lengthened the first dripping time of the ice cream. Significant ($p<0.05$) variation in hardness and adhesiveness of pea protein ice cream was recorded with vary in content of inulin in the product formulation. Maximum overrun of 38.48±2.56% was achieved with the addition of 4% inulin to the ice cream. The fat content in the ice cream formulations replaced with 6 and 8% of inulin resulted in lowering flavour and overall acceptability score. Results demonstrating that textural properties and sensory attributes can be affected by the amount of inulin added to the vegan pea protein ice cream.

Key-words: Inulin, hardness, overrun, pea protein, ice cream, vegan

1. Introduction

The worldwide interest in veganism has been raised in recent years, ranging from 1 to 5% of the population that consumes plant-based meals (Radnitz et al., 2015). Veganism involves in diet and lifestyle choice that avoids consumption of all animal products, including meat, dairy products, honey, eggs, and other products (Cramer et al., 2017). The major reasons for the practice of veganism are due to moral, ethical, animal welfare, dietary restrictions, and the search for improvements in health, with emphasis on issues related to health and ethics (Fox & Ward, 2008; Ruby, 2012; Dyett et al., 2013). In this scenario, the dairy alternative products made up of plant-based proteins are suitable for treating allergies, lactose intolerant, and vegan diets (Cramer et al., 2017; Wangcharoen, 2012; W. Chen et al., 2019).

Usage of pea protein isolate (more than 80% of protein content) is most affordable and sustainable in developing dairy alternatives as they meet functional and nutritional properties with the least allergens (Lu et al., 2020). Pea is mainly composed of 65 – 80% of globulin proteins, 10 – 20% of albumin proteins and high content of lysine (Guler-Akin et al., 2021). Pea protein (most times, pea protein hydrolysates and specific peptide fractions) has antioxidant, antihypertensive, anti-inflammatory, lowering cholesterol, and modulating intestinal bacteria activities (Li & Aluko, 2010; Liao et al., 2019). Besides, the functional properties like foaming, emulsifying, oil-holding capacity, water holding capacity, solubility, and food texturing are the most promising features to apply pea protein isolates in the manufacturing of plant-based dairy alternatives (Ge et al., 2020; Guler-Akin et al., 2021; Liao et al., 2019).

Hence, the development of pea protein based vegan ice cream can be an attractive dairy ice cream alternative to meet the growing demand for products intended for specific diets, with least allergic compounds and containing ingredients with nutritional and physiological properties (Aboulfazli et al., 2016; Crizel et al., 2014; Cruz et al., 2009). Although vegan ice cream brings health benefits, they can contain high level of fat, with negative impact on human health (Akbari et al., 2019; Patil & Banerjee, 2017; Radnitz et al., 2015). Therefore, studies to develop acceptable modified low-fat vegan ice cream formulations are required, which can provide pleasant experience to the consumer while consumption. In this context, inulin as a fat replacer in the pea protein ice creams seems to be a very good option, considering the fact that the traditional dairy ice cream formulations contain fat in between 10 to 16% (Akbari et al., 2019; Patil & Banerjee, 2017). Commercial grades of inulin are neutral, clean flavor and are used to improve mouthfeel, stability, acceptability of low-fat ice creams and have unique ability to form a gel-like network by holding water to improve ice cream texture. (Karaca et al., 2009; Pintor et al., 2017; Samakradhamrongthai et al., 2021; Shoaib et al., 2016).

Moreover, inulin is a dietary fiber, that can act as a prebiotic as a fermentable food for gut microbiota has a beneficial impact on a human host by improving mineral absorption and stimulation of immune functions, reduced risks of irritable bowel diseases and constipation (Ahmed & Rashid, 2019; Akram et al., 2019; Shoaib et al., 2016). Inulin can also be safely used as a bulking agent or thickener and soluble fiber without any limits in low calorific diet foods (Ahmed & Rashid, 2019; Samakradhamrongthai et al., 2021). As far as is known, there is no study on pea protein ice cream production with inulin as a fat replacer. The aim of the current study was to develop a low-fat pea protein ice-cream as a new functional food, which is a new alternative to dairy ice cream using inulin as a fat replacer and, simultaneously evaluating the inulin effect on textural properties and sensory attributes of the developed vegan ice cream.

2. Materials and methods

2.1. Materials

Pea protein isolates (79% of protein content) (Danisco, Denmark), locally sourced sugar (AB 'Nordic Sugar Kedainiai', Lithuania) and rapeseed oil (AS 'Scanola Baltic', Estonia), Blueberry juice concentrate (SIA 'Puratos', Latvia), stabilizer mix Excelais 602 (Mono- and diglycerides of fatty acids, Guar gum, Locust bean gum, Carrageenan) (Rikevita SDN. BHD, Malaysia), Orafti HPX inulin (Beneo, Belgium) and water were used as ingredients for ice-cream production.

2.2. Ice-cream preparation

The formulations developed for the ice-cream mixes to employ inulin as a fat (rapeseed oil) replacer are presented in the Table 1. The ice-cream mixes were made by homogenizing all ingredients in water at 3000 rpm for 5 min using IKA® T18 digital ULTRA TURRAX® high shear mixer (IKA®, Germany) and followed by pasteurization on Guardian™ 7000 magnetic stirrer (Ohaus®, USA) speed of 900 rpm with heating plate at 85 °C for 10 min. The mix was immediately cooled to 20 °C using ice filled sink and aged at 4 °C temperature around 2 h to hydrate all the ingredients. Freezing of mixes were done at around -12 °C temperature using batch type Frigomat G10 ice cream freezer (Frigomat, Italy) for 7 min and filled in 100 ml sampling cups for hardening the ice cream in hardening chamber (Midea, China) at -18±1 °C around 14 h.

2.3. Overrun

Overrun was measured by comparing the weight of the ice-cream mix and ice cream in a fixed volume (100 ml) container referring to the method mentioned in (Muse & Hartel, 2004). Ten overrun measurements in percentage were taken per sample using the following equation:

$$\%\ of\ overrun = \frac{weight\ of\ ice\ cream\ premix - weight\ of\ ice\ cream}{weight\ of\ icecream} \times 100 \qquad (1)$$

2.4. Melting rate

The melting rate of the hardened (-18 °C for 1day) ice cream sample around 100 ml was measured by placing the ice cream on 1 mm stainless steel mesh at ambient temperature (20 $\pm$ 1 °C), and weight of the melted ice cream was noted every 10 min (Pintor et al., 2017). The plot of bar diagram was developed using percentage of the melted ice cream versus time and measurements were taken in triplicate.

2.5. Textural analysis

Textural analysis was conducted at ambient temperature (20 ± 1 °C) using TA.HDplus Texture Analyser (Stable Micro Systems Ltd, England) equipped with 2.5 cm diameter stainless steel cylindrical probe. The frozen sample stored at -18 °C was removed from freezer shortly before the analysis. The texture analysis conditions were as follows: penetration depth, 15 mm; trigger force, 5.0 g; probe speed during penetration, 3.3 mm s^{-1}; probe speed pre and post penetration, 3.0 mm s^{-1}. The probe was penetrated in one place on the largest smooth surfaces of the ice cream samples, which remained in the plastic cup and six measurements were recorded for each sample. Hardness and adhesiveness were calculated as peak force (N) during penetration and negative area (N.s) of plot obtained during withdrawal of probe, respectively (Akalın et al., 2008).

2.6. Sensory analysis

The sensory evaluation of pea protein ice cream samples was performed using a 9-point Hedonic scale with noted 1 - as poor, 5 - as average, and 9 - as excellent by a panel of nine semi-trained judges (4 males and 5 females). The panelists were the University master degree non-smoking students aged between 22 - 30 years. They were asked to taste each sample and indicate the degree of liking for each sample on a given sensory scale. Each panelist was trained in four 30-min sessions were held over 1 month for basic aspects and the differences concern all the attributes of the samples. The first session was used to introduce the hedonic scale, spooning technique, and amount of ice cream to use for assessment. The remaining sessions were held on introducing attributes flavor, texture, and color. The ice cream cups with 50g of ice cream were served immediately after withdrawing the cups from the freezer chest after 24 h of storage at around -18 °C and promptly offered to the panelists. The samples were coded with three-digit random numbers in odorless cups with all the orders of servings completely randomized referring to the method mentioned in (Herald et al., 2008; Roland et al., 1999; Sharma et al., 2017).

2.7. Data processing

Data analysis and acquisition were completed using Microsoft Office Excel v16.0 and SPSS 19.0 software. Analysis of variance (ANOVA) and Tukey's test were used to compare means, differences were considered significant at a level of $p<0.05$.

3. Results and discussion

3.1. Melting rate

As per the results obtained shown in the Figure 1, no ice cream showed melting until 40 min of the initial time and complete meltdown of all ice creams did not happened even after 130 min at room temperature, these durations are longer than the conventional dairy ice cream melting times. According to da Silva & Lannes (2011), Guler-Akin et al. (2021), and Loffredi et al. (2021), the time taken for first dripping was below 20 min and complete meltdown happened within 60 min in ice cream made up of milk-based ingredients and they mentioned, the type of ingredients used in ice cream preparation influence the melting behavior. The water binding and retention capacities of pea protein isolate used in the current formulation were capable of forming a stable gel matrix with water molecules, and hence resulted in the slower melting of ice cream, the similar phenomenon was explained by Boye et al. (2010). Guler-Akin et al. (2021) showed the addition of pea protein isolate to the ice cream formulation prolonged the first dripping time and complete melting time, simultaneously no melting was observed in complete pea protein based ice cream. Sivasankari et al. (2019) also reported that the addition of pulse protein leads to immobilization of water molecules to move freely among the other molecules of the mix due formation of stable gel network led to reduce the melting of ice cream.

Addition of fibers and polysaccharides to the ice cream formulation can improve the melting properties of the ice cream (Hassan & Barakat, 2018; Pintor et al., 2017). The current study results demonstrated that, increase in inulin content as a fat replacer can impact on the melting properties of the ice cream, the ice creams added with 6% and 8% of inulin required more than 50 min of time for the first dripping when compared to the ice creams added with 2% and 4% (around 40 min) and the percentages of ice cream melted after 130 min in inulin containing samples were less than the sample without inulin. These results can be attributed to, the inulin water retention and immobilization properties in large amounts, causes the less crystallization and lower meting rate (Akalın et al., 2008; Balthazar et al., 2018; Pintor et al., 2017). Similarly, addition of citrus fibers (1.8 g/100g) to ice cream formulation increased the starting time of melting approximately from 20 to 50 min due to higher water absorption of fiber particles (Loffredi et al., 2021).

The study Guler-Akin et al. (2021) showed, no melting of vegan ice cream (contains 9% pea protein isolate) was observed during whole analysis time of around 105 min. Contrast results of around 40 min for initial meltdown time was observed in this work as the ice cream was made up of only 5% pea protein isolate. These results can be explained as pea protein isolates are capable of imbibing water molecules to form a strong stable network in ice cream, reflects in longer meltdown rate (Gabbi et al., 2018; Ghandehari Yazdi et al., 2020).

3.2. Overrun

The vegan pea protein ice cream formulation without inulin produced the overrun of 34.8±2.3% as shown in the Table 2. The author Guler-Akin et al. (2021) achieved overrun of around 16% with complete pea protein based vegan ice cream and found negative correlation in between amount of pea protein isolate and overrun values of ice cream due to very high viscosity gel-matrix formation, which may negatively impact the incorporation of air during freezing process (Sivasankari el., 2019). Pereira et al. (2011) and Badıllı (2020) reported that addition of soy protein extract and chick pea flour, respectively, to the ice cream formulation results higher mix viscosities, reflects in lower overrun values. Moreover, changes in the content of inulin as a fat replacer in the current research showed significant ($p<0.05$) variation in overrun values in the ice cream. The formulations added with 2 and 4% of inulin as a fat replacer resulted in significant ($p<0.05$) higher overrun values of 36.2±3.54 and 38.48±2.56, respectively, compared to the formulations with 6 and 8% of inulin content. These results were in agreement with Akalın et al. (2008), Pintor et al. (2017), and Samakradhamrongthai et al. (2021), they reported that using inulin in-between 2 and 4% as a fat replacer in the reduced fat ice cream improves the overrun due to rise in viscosities, which promotes more efficient air incorporation and the formation of smaller air cells during freezing. However, the fat plays the key role in ice cream overrun by forming a fat globular membrane on the surface of the air bubble during the mixing and freezing process. Hence, lowering the amount of fat in ice cream causes reduction in viscosity since less availability of fat to aggregate around the air bubble and results in lower overrun (Pintor et al., 2014). Similarly, significant reduction ($p<0.05$) in overrun values of ice cream formulations D and E were observed with increase in inulin content above 4% as a fat replacer since the excess inulin interacts with aqueous phase in ice cream lowers the concentration of free water resulting in the ice cream mix being thicker with higher viscosity while lowering the overrun (Samakradhamrongthai et al., 2021).

3.3. Hardness and adhesiveness

Hardness of ice cream is the reflection of the structure of the emulsion formation with fat, water, air, and protein during the homogenization and freezing period of ice cream mix. Thus, the reduction in fat content increased the hardness of ice cream due to increase in free water molecules in the ice cream can form a larger ice crystal during freezing to give a hardened ice cream. But, when the fat replaced by inulin would improve the hardness of ice cream as inulin is capable of adsorbing the free water molecules in the emulsion solution of ice cream, so that the reduction in ice crystal formation leads to a softer ice cream (Akbari et al., 2016; Mahdian & Karazhian, 2018; Pintor et al., 2014). The present study results (Table 2) depicted the reduction in hardness of ice cream while increasing inulin content as a fat replacer, the maximum value of hardness 342.23±32.39 N ($p<0.05$) was observed when ice cream was with zero added inulin and least value of hardness 192.47±37.03 ($p<0.05$) was observed when

8% of inulin added. These observations are comparable with the results reported by El-Nagar et al. (2002), they reported that application of inulin as a fat replacer in the low-fat ice cream at the level of 5, 7 and 9% showed a significant reduction in the hardness of ice cream. The higher hardness value of the sample without inulin in the present study can be demonstrated as the pea protein isolate in the ice cream formulation capable of formation of gel network with the free water (Boye et al., 2010; Guler-Akin et al., 2021) during homogenization of mix and the possibility of larger ice crystal formation due to mobile water while freezing (Mahdian & Karazhian, 2018) compared to inulin added ice cream.

Significantly ($p<0.05$) higher adhesiveness values observed with increasing inulin content in the formulation, higher value of -16.27±3.26 N.s was produced with addition of 8% inulin. These results are in agreement with (Akbari et al., 2016), they produced significantly ($p<0.05$) higher adhesive values while increasing the inulin content as a fat replacer compared to 10% fat containing ice-cream. El-Nagar et al. (2002) demonstrated that, higher the inulin content in yog-ice cream reflects in higher stickiness due to the formation of viscous-gel matrix. Similar adhesiveness values in reduced and low-fat ice creams added with around 5% modified starch reported by Aime et al. (2001) were in between -13.9 to -20.7 N and Akalın et al. (2008) produced around 11 N of adhesiveness value in a low-fat ice cream containing 4% of inulin.

3.4. Sensory

The pea protein ice cream with no inulin content (Figure 2) resulted in the average sensory scores (around 5) for all attributes during sensory analysis can be attributed to the aroma compounds in the pea proteins and their texturing properties, which can negatively affect the overall acceptability of pea protein ice cream. The interest in alternative pea protein isolates in the food industry has raised recently due to its high nutritional value. However, to obtain pea protein isolate, peas undergo series of pH and temperature changing process steps causing the non-enzymatic Maillard reactions leading to off-flavor compounds formation in protein isolate (Azarnia et al., 2011). According to Guler-Akin et al. (2021), the addition of pea protein isolate as substitution to milk powder in the production of both dairy and vegan ice creams reduces the sensory properties.

Moreover, the results revealed that pea protein ice creams added with 2 and 4% of inulin produced similar scores as 0% inulin pea protein ice cream for flavour, texture, color, and overall acceptability. But a significant reduction ($p<0.05$) in flavor and overall acceptability scores of the pea protein ice creams was observed when added with 6 and 8% of inulin to the formulations (D and E) as a fat replacer compared to 0, 2, and 4% inulin added formulations (A, B, C). The study Li et al. (1997) explained, the reduction in fat content in the mix negatively influence the flavor and overall acceptability of the ice cream since the fat works as a flavor carrying medium. No better sensory scores were achieved during the present work with the addition of inulin (2, 4, 6, and 8%) as a fat replacer to the pea protein ice cream as compared to no inulin added pea protein ice cream.

4. Conclusions

The present study demonstrated that a rise in inulin content in pea protein ice cream significantly reduced the hardness compared to inulin-free ice cream. Initial dripping and overall melting times of the pea protein ice cream are dependable on both inulin and pea proteins. More than 4% addition of inulin to the pea protein ice cream as a fat replacer can negatively impact the overrun values, but the formulations with 2 and 4% of inulin produced higher overrun. Similar sensory scores of pea protein ice creams with 2 and 4% of inulin were observed as compared to 0% inulin added ice cream. Hence, there is a scope for inulin as a functional ingredient while producing low-fat vegan pea protein ice cream. But, further studies on the optimization of inulin as a fat replacer should be done to find out the most suitable amount of inulin to be added in the vegan pea protein ice cream manufacturing.

Acknowledgement

The present research has been conducted by "Nature Foods" Ltd. with the financial support from the European Regional Development Fund (contract No. 1.2.1.1/18/A/002) within the framework of the research project No.4. - "Development of new and innovative products at Nature Foods" supported by Latvian Food Industry Competence Centre. We would like to thank Dr. Ruta Galoburda and Faculty of Food Technology, Latvia University of Life Sciences and Technologies for providing research lab facilities.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References:

1. Aboulfazli, F., Baba, A. S., & Misran, M. (2014). Effect of vegetable milks on the physical and rheological properties of ice cream. *Food Science and Technology Research*, *20*(5), 987–996. https://doi.org/10.3136/fstr.20.987.
2. Ahmed, W., & Rashid, S. (2019). Functional and therapeutic potential of inulin: A comprehensive review. *Critical Reviews in Food Science and Nutrition*, *59*(1), 1–13. https://doi.org/10.1080/10408398.2017.1355775.
3. Aime, D. B., Arntfield, S. D., Malcolmson, L. J., & Ryland, D. (2001). Textural analysis of fat reduced vanilla ice cream products. *Food Research International*, *34*(2–3), 237–246. https://doi.org/10.1016/S0963-9969(00)00160-5.
4. Akalın, A. S., Karagözlü, C., & Ünal, G. (2008). Rheological properties of reduced-fat and low-fat ice cream containing whey protein isolate and inulin. *European Food Research and Technology*, *227*(3), 889–895. https://doi.org/10.1007/s00217-007-0800-z.
5. Akbari, M., Eskandari, M. H., & Davoudi, Z. (2019). Application and functions of fat replacers in low-fat ice cream: A review. *Trends in Food Science and Technology*, *86*, 34–40. https://doi.org/10.1016/j.tifs.2019.02.036.
6. Akbari, M., Eskandari, M. H., Niakosari, M., & Bedeltavana, A. (2016). The effect of inulin on the physicochemical properties and sensory attributes of low-fat ice cream. *International Dairy Journal*, *57*, 52–55. https://doi.org/10.1016/j.idairyj.2016.02.040.
7. Akram, W., Garud, N., & Joshi, R. (2019). Role of inulin as prebiotics on inflammatory bowel disease. *Drug Discoveries & Therapeutics*, *13*(1), 1–8. https://doi.org/10.5582/ddt.2019.01000.
8. Azarnia, S., Boye, J. I., Warkentin, T., Malcolmson, L., Sabik, H., & Bellido, A. S. (2011). Volatile flavour profile changes in selected field pea cultivars as affected by crop year and processing. *Food Chemistry*, *124*(1), 326–335. https://doi.org/10.1016/j.foodchem.2010.06.041.
9. Badilli, A. G. (2020). *Yağı azaltılmış fonksiyonel dondurma üretiminde süt tozu yerine nohut ununun kullanılabilme olanaklarının araştırılması/Investigation of possibilities of chickpea flour usage opportunities instead of milk powder in reduced fat functional ice cream production* (Doctoral dissertation).
10. Balthazar, C. F., Silva, H. L., Esmerino, E. A., Rocha, R. S., Moraes, J., Carmo, M. A., ... & Cruz, A. G. (2018). The addition of inulin and Lactobacillus casei 01 in

sheep milk ice cream. *Food chemistry*, *246*, 464-472. https://doi.org/10.1016/j.foodchem.2017.12.002.

11. Boye, J., Zare, F., & Pletch, A. (2010). Pulse proteins: Processing, characterization, functional properties and applications in food and feed. *Food Research International*, *43*(2), 414–431. https://doi.org/10.1016/j.foodres.2009.09.003.
12. Chen, W., Liang, G., Li, X., He, Z., Zeng, M., Gao, D., ... & Chen, J. (2019). Effects of soy proteins and hydrolysates on fat globule coalescence and meltdown properties of ice cream. *Food Hydrocolloids*, *94*, 279-286. https://doi.org/10.1016/j.foodhyd.2019.02.045.
13. Cramer, H., Kessler, C. S., Sundberg, T., Leach, M. J., Schumann, D., Adams, J., & Lauche, R. (2017). Characteristics of Americans Choosing Vegetarian and Vegan Diets for Health Reasons. *Journal of Nutrition Education and Behavior*, 49(7), 561-567. http://dx.doi.org/10.1016/j.jneb.2017.04.011.
14. Crizel, T. M., Araujo, R. R., Rios, A. O., Rech, R., & Flôres, S. H. (2014). Orange fiber as a novel fat replacer in lemon ice cream. *Food Science and Technology*, 34(2), 332-340. http://dx.doi.org/10.1590/fst.2014.0057.
15. Cruz, A. G., Antunes, A. E. C., Sousa, A., Faria, J. A. F., & Saad, S. M. I. (2009). Ice-cream as a probiotic food carrier. *Food Research International*, 42(9), 1233-1239. http://dx.doi.org/10.1016/j.foodres.2009.03.020
16. da Silva, E., & Lannes, S. C. da S. (2011). Effect of different sweetener blends and fat types on ice cream properties. *Ciencia e Tecnologia de Alimentos*, *31*(1), 217–220. https://doi.org/10.1590/S0101-20612011000100033.
17. das Graças Pereira, G., de Resende, J. V., de Abreu, L. R., de Oliveira Giarola, T. M., & Perrone, I. T. (2011). Influence of the partial substitution of skim milk powder for soy extract on ice cream structure and quality. *European Food Research and Technology*, *232*(6), 1093-1102. https://doi. org/10.1007/s00217-011-1483-z.
18. Dyett, P. A., Sabate, J., Haddad, E., Rajaram, S., & Shavlik, D. (2013). Vegan lifestyle behaviors: An exploration of congruence with health-related beliefs and assessed health indices. *Appetite*, 67(0), 119-124. http://dx.doi.org/10.1016/j.appet.2013.03.015
19. El-Nagar, G., Clowes, G., Tudorică, C. M., Kuri, V., & Brennan, C. S. (2002). Rheological quality and stability of yog-ice cream with added inulin. *International Journal of Dairy Technology*, *55*(2), 89-93. https://doi:10.1046/j.1471-0307.2002.00042.x.
20. Fox, N., & Ward, K. (2008). Health ethics and environment: A qualitative study of vegetarian motivations. *Appetite*, 50(2-3), 422- 429. http://dx.doi.org/10.1016/j.appet.2007.09.007.
21. Gabbi, D. K., Bajwa, U., & Goraya, R. K. (2018). Physicochemical, melting and sensory properties of ice cream incorporating processed ginger (Zingiber officinale). *International Journal of Dairy Technology*, *71*(1), 190–197. https://doi.org/10.1111/1471-0307.12430.
22. Ghandehari Yazdi, A. P., Barzegar, M., Ahmadi Gavlighi, H., Sahari, M. A., & Mohammadian, A. H. (2020). Physicochemical properties and organoleptic aspects of ice cream enriched with microencapsulated pistachio peel extract. *International Journal of Dairy Technology*, *73*(3), 570–577. https://doi.org/10.1111/1471-0307.12698.
23. Guler-Akin, M. B., Avkan, F., & Akin, M. S. (2021). A novel functional reduced fat ice cream produced with pea protein isolate instead of milk powder. *Journal of Food Processing and Preservation*, *March*, 1–11. https://doi.org/10.1111/jfpp.15901.

24. Hassan, M. F. Y., & Barakat, H. (2018). Effect of Carrot and Pumpkin Pulps Adding on Chemical, Rheological, Nutritional and Organoleptic Properties of Ice Cream. *Food and Nutrition Sciences*, *09*(08), 969–982. https://doi.org/10.4236/fns.2018.98071.
25. Herald, T. J., Aramouni, F. M., & Abu-Ghoush, M. H. (2008). Comparison study of egg yolks and egg alternatives in French vanilla ice cream. *Journal of texture studies*, *39*(3), 284-295.
26. Karaca, O. B., Güven, M., Yasar, K., Kaya, S., & Kahyaoglu, T. (2009). The functional, rheological and sensory characteristics of ice creams with various fat replacers. *International Journal of Dairy Technology*, *62*(1), 93–99. https://doi.org/10.1111/j.1471-0307.2008.00456.x.
27. Li, Z., Marshall, R., Heymann, H., & Fernando, L. (1997). Effect of Milk Fat Content on Flavor Perception of Vanilla Ice Cream. *Journal of Dairy Science*, *80*(12), 3133–3141. https://doi.org/10.3168/jds.S0022-0302(97)76284-2.
28. Loffredi, E., Moriano, M. E., Masseroni, L., & Alamprese, C. (2021). Effects of different emulsifier substitutes on artisanal ice cream quality. *Lwt*, *137*, 110499. https://doi.org/10.1016/j.lwt.2020.110499.
29. Mahdian, E., & Karazhian, R. (2013). Effects of fat replacers and stabilizers on rheological, physicochemical and sensory properties of reduced-fat ice cream. *Journal of Agricultural Science and Technology*, *15*(6), 1163-1174.
30. Muse, M. R., & Hartel, R. W. (2004). Ice cream structural elements that affect melting rate and hardness. *Journal of Dairy Science*, *87*(1), 1–10. https://doi.org/10.3168/jds.S0022-0302(04)73135-5.
31. Patil, A. G., & Banerjee, S. (2017). Variants of ice creams and their health effects. *MOJ Food Process Technol*, *4*(2), 58-64. http://doi.org/ 10.15406/mojfpt.2017.04.00088.
32. Pintor, A., Escalona-Buendía, H. B., & Totosaus, A. J. I. F. R. J. (2017). Effect of inulin on melting and textural properties of low-fat and sugar-reduced ice cream: optimization via a response surface methodology. *International Food Research Journal*, *24*(4), 1728.
33. Pintor, A., Severiano-Pérez, P., & Totosaus, A. (2014). Optimization of fat-reduced ice cream formulation employing inulin as fat replacer via response surface methodology. *Food Science and Technology International*, *20*(7), 489–500. https://doi.org/10.1177/1082013213493100.
34. Radnitz, C., Beezhold, B., & Dimatteo, J. (2015). Investigation of lifestyle choices of individuals following a vegan diet for health and ethical reasons. *Appetite*, 90, 31-36. http://dx.doi.org/10.1016/j.appet.2015.02.026.
35. Roland, A. M., Phillips, L. G., & Boor, K. J. (1999). Effects of fat content on the sensory properties, melting, color, and hardness of ice cream. *Journal of Dairy Science*, *82*(1), 32-38.
36. Ruby, M. B. (2012). Vegetarianism: A blossoming field of study. *Appetite*, 58(1), 141-150. http://dx.doi.org/10.1016/j.appet.2011.09.019.
37. Samakradhamrongthai, R. S., Jannu, T., Supawan, T., Khawsud, A., Aumpa, P., & Renaldi, G. (2021). Inulin application on the optimization of reduced-fat ice cream using response surface methodology. *Food Hydrocolloids, 119*, 106873. https://doi.org/10.1016/j.foodhyd.2021.106873.
38. Sharma, M., Singh, A. K., & Yadav, D. N. (2017). Rheological properties of reduced fat ice cream mix containing octenyl succinylated pearl millet starch. *Journal of Food Science and Technology*, *54*(6), 1638–1645. https://doi.org/10.1007/s13197-017-2595-7.

39. Shoaib, M., Shehzad, A., Omar, M., Rakha, A., Raza, H., Sharif, H. R., Shakeel, A., Ansari, A., & Niazi, S. (2016). Inulin: Properties, health benefits and food applications. *Carbohydrate Polymers*, *147*, 444–454. https://doi.org/10.1016/j.carbpol.2016.04.020.
40. Sivasankari, R., Hemalatha, G., Amutha, S., Murugan, M., Vanniarajan, C., & Umamaheswari, T. (2019). Physical and Sensory Properties of Ice Cream as Influenced by Pulse Protein Concentrates. *European Journal of Nutrition & Food Safety*, *9*(4), 322–328. https://doi.org/10.9734/ejnfs/2019/v9i430079.
41. Wangcharoen, W. (2012). Development of ginger-flavoured soya milk ice cream: comparison of data analysis methods. *Maejo international journal of science and technology*, *6*(3), 505-513.

LEGENDS TO FIGURES

Figure 1. Meting behavior of pea protein ice cream with 0, 2, 4, 6, and 8% of inulin as a fat replacer

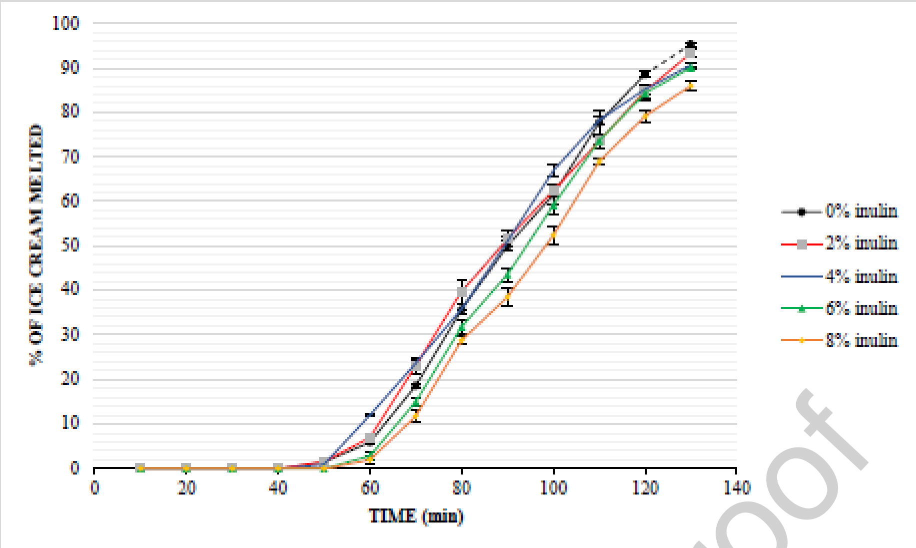
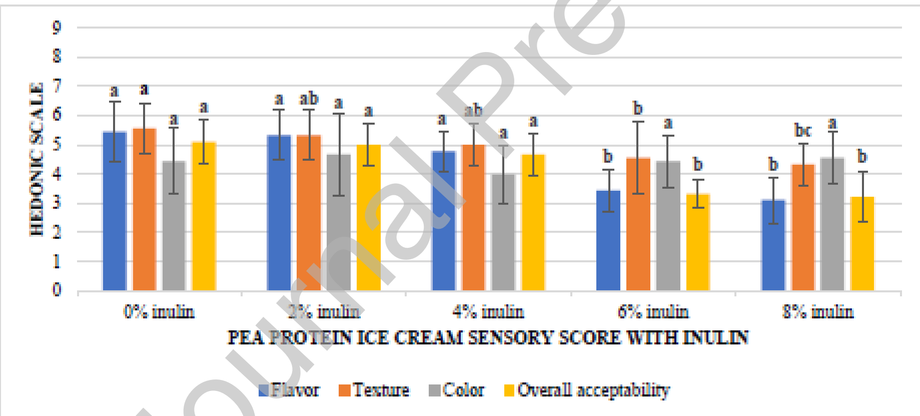


Figure 2. Sensory score of pea protein ice cream with 0, 2, 4, 6, and 8% of inulin as a fat replacer



*Different letters (a, b, c) show significant differences ($p<0.05$) in flavour, texture, color and overall acceptability of pea protein ice creams (with inulin 0, 2, 4, 6, and 8%).

LEGENDS TO TABLES

Table 1. Formulations of pea protein ice-cream with inulin as a fat replacer

Formulation	Pea protein isolate (w/v %)	Sugar (w/v %)	Rapeseed oil (v/v %)	Stabilizing mixture EXCEL AIS 602 (w/v %)	Blueberry juice concentrate (w/v %)	Inulin (w/v %)	Water (v/v %)
A	5	20	10	0.7	2	0	62.3
B	5	20	8	0.7	2	2	62.3
C	5	20	6	0.7	2	4	62.3
D	5	20	4	0.7	2	6	62.3
E	5	20	2	0.7	2	8	62.3

Table 2. Changes in overrun, hardness, and adhesiveness of pea protein ice creams with 0, 2, 4, 6, and 8% of inulin as a fat replacer

	0% inulin	2% inulin	4% inulin	6% inulin	8% inulin
Overrun (%)	34.8 ± 2.3^{a}	36.2 ± 3.54^{ab}	38.48 ± 2.56^{bc}	28.21 ± 3.26^{d}	25.78 ± 3.06^{e}
Hardness (N)	342.23 ± 32.39^{a}	209.18 ± 39.06^{b}	208.13 ± 28.65^{b}	201.10 ± 22.78^{c}	192.47 ± 37.03^{d}
Adhesiveness (N.s)	-5.69 ± 3.5^{a}	-10.11 ± 4.56^{b}	-13.51 ± 4.62^{c}	-12.73 ± 6.72^{c}	-16.27 ± 3.26^{d}

*Different superscript letters show significant differences (p<0.05) in a row