

Impact of stabilizers on the freezing process, and physicochemical and organoleptic properties of coconut milk-based ice cream

Małgorzata Góral^a, Katarzyna Kozłowicz^b, Urszula Pankiewicz^a, Dariusz Góral^{b,*}, Franciszek Kluza^b, Agnieszka Wójtowicz^c

^a Department of Analysis and Food Quality Assessment, Faculty of Food Science and Biotechnology, University of Life Sciences in Lublin, Skromna 8, 20-704 Lublin, Poland

^b Department of Biological Bases of Food and Feed Technologies, Faculty of Production Engineering, University of Life Sciences in Lublin, Doświadczalna 44, 20-280 Lublin, Poland

^c Department of Thermal Technology and Food Process Engineering, Faculty of Production Engineering, University of Life Sciences in Lublin, Doświadczalna 44, 20-280 Lublin, Poland

ARTICLE INFO

Keywords:

Ice cream
Coconut milk
Inulin
Locust bean gum (LBG)

ABSTRACT

The objective of the study was to characterize the effects of selected stabilizers on the freezing process and the physicochemical properties of coconut milk ice cream. Two stabilizers were used: inulin (0.8, 1.6, 2.4, 3.2 and 4 g/100 g of the mixture) and locust bean gum (LBG) (0.2, 0.4, 0.6 and 0.8 g/100 g of the mixture). Freezing process was performed in two stages. After the temperature of the ice cream mixtures reached -6°C , they were hardened at -30°C for 24 h. Then the samples were examined for their chemical composition, overrun, melting time and melting resistance, hardness and colour. The results showed that increasing concentration of inulin and LBG resulted in a decrease in the cryoscopic temperature and melting time of ice cream. On the other hand, ice cream produced from the mixtures containing higher inulin concentration and lower LBG concentration were characterized by higher overrun. Addition of inulin and LBG cause statistically significant changes in hardness of ice cream. The differences in colour of tested ice creams were shown. The highest scores in the sensory evaluation were obtained for ice cream with LBG and 0.8 g/100 g and 4 g/100 g of inulin.

1. Introduction

Consumer ice cream is one of the most popular desserts. The global consumption of this product is about 2 L per person per year. It is projected that the development of the industry and the increase in wealth of people will result in higher demand for ice cream (Agrawal, 2016). According to the definition of the European Ice Cream Association (Euroglaces, 2017), ice cream is a food product containing all food ingredients (amongst them all additives) authorized by the current provisions, which has structure and texture generated by freezing, and that is stored, transported, sold and consumed in the frozen state. Ice creams are physico-chemical complexes containing air bubbles which are dispersed in the continuous phase. This phase consists of the partially crystalline fat globules and casein micelles as discrete particles in a solution of sugars, insoluble mineral salts, dispersed whey protein, stabilizers, etc. The freezing process is a decisive factor affecting the properties of ice cream. There are two basic industrial methods of making ice cream: quiescent freezing, in which the liquid product is not stirred when freezing and active freezing which involves stirring (Clark,

Jung, & Lamsal, 2014). The second method is more complicated but most often used. In this method freezing is carried out in two stages. The initial freezing of the mixture to -6°C , until it achieves plasticity, is carried out in the freezers. The purpose of this stage of production is partial water crystallization. Approximately 55% of the freezable water is frozen. Such obtained type of ice cream is called soft serve. At this stage, the mixture (at about 4°C) passes from the ageing tanks to overrun compartments. Freezers are most often built from a cylindrical drum surrounded by a cooling jacket through which the cooling agent flows. The resulting soft serve ice cream is subjected to a second freezing (hardening) step by reducing the temperature of the mixture from about -6°C to -25°C corresponding to 80–90% of the frozen water (Clark, 2012).

The main ingredient of commonly consumed ice cream is cow milk. Although it contains a number of substances beneficial to human body, such as proteins, milk fat, lactose, vitamins and mineral compounds, it is not recommended for some consumer groups e.g. people who are lactose intolerant (Lopata, 2010; Mattar, de Campos Mazo, & Carrilho, 2012; Misselwitz et al., 2013; Usai-Satta, Scarpa, Oppia, & Cabras,

* Corresponding author.

E-mail address: dariusz.goral@up.lublin.pl (D. Góral).

2012). Also, milk lipids after ingestion may increase blood cholesterol levels (Aboufazi, Shori, & Baba, 2016). In addition, milk is known to be one of eight major human allergens and there is currently no effective way to completely reduce the allergy to cow's milk (Boye, Rajamohamed, & Britten, 2011; Lifschitz & Szajewska, 2015; Verhoeck et al., 2015).

Substitutes of milk and its products make an alternative. The United Nations Food and Agriculture Organization (FAO) recommends substitutes for dairy products containing at least 3.5 g/100 g fat, 3.5 g/100 g protein and 5 g/100 g carbohydrates, which are all vegetable milk (Protein Advisory Group, 1972). Coconut milk is regarded a good choice as it is easily digested and a rich source of nutrients. Besides, it is abundant in calcium, phosphorus, potassium as well as C, E and B₆ vitamins. Notably, coconut milk contains proteins with large quantities of essential amino acids, lipids and antioxidants (Yuliana, Ranga, & Rakhmiati, 2010; Aboufazi, Baba, & Misran, 2015; Fuangpaiboon & Kijroongrojana, 2015; Sridhar, Roopa, Varadaraj, & Vijayendra, 2015).

It is currently technologically possible to produce ice creams that are free of allergenic animal products and contain functional additives in their composition. Frozen desserts can serve as carriers for nutrients (Lin, 2012; Soukoulis, Fisk, & Bohn, 2014; Wichamane, Acharaphan, & Santad, 2016) such as antioxidants and prebiotics (Aboufazi et al., 2016; Soukoulis et al., 2014; Soukoulis, Lebesi, & Tzia, 2009).

The consumption of ice cream containing elderberry (*Sambucus nigra*) contributes to the deactivation of free radicals, vitamins and inhibits the lipid peroxidation processes. Elderberry is used in the prevention of cancer, vascular diseases and diabetes. It is characterized by antiviral and antimicrobial properties supporting the treatment of influenza and colds (Kong, 2009; Mikulic-Petkovsek, Ivancic, Schmitzer, Veberic, & Stampar, 2016; Sidor & Gramza-Michałowska, 2015). Other important ice cream ingredients treated as functional may be inulin and locust bean gum. Inulin is a polymer consisting of fructose molecules that naturally occurs in plants and certain microorganisms. It is often used as a fat substitute in food products. Thanks to its ability to bind water molecules, inulin plays an important role in stabilizing the texture of the product. It is also a nutritionally valuable prebiotic (Akbari, Eskandari, Niakosari, & Bedeltavana, 2016). Locust bean gum is a natural polysaccharide produced from carob tree seed. Like other polysaccharide hydrocolloids, it is a commonly used as stabilizing additive for ice creams due to its ability to thicken and gelate the product (Barak & Mudgil, 2014; Dłużewska, Gazda, & Leszczyński, 2003).

The objective of the work was to characterize the effects of selected stabilizers on the freezing process and the physicochemical properties of coconut milk ice cream.

2. Material and methods

2.1. Ingredients for ice cream production

The following ingredients were used for ice cream production: sterilized coconut milk (LIDL Stiftung, Co. KG. Germany), cane sugar (Sante, Poland), elderberry syrup (sugar, water, concentrated juice with elderberry fruits 19%) (Agros Nova Sp. Z o. o., Poland) and sunflower lecithin (Agnex, Poland). Composition of the mixture was modified by addition of different amounts of stabilizers (relative to the mass of the mixture): inulin (0.8; 1.6; 2.4; 3.2; 4 g/100 g) (Agnex, Poland) and LBG (0.2; 0.4; 0.6; 0.8 g/100 g) (Biozoon GmbH, Germany).

2.2. Preparation of ice cream

The ice cream mixture was prepared traditionally by weighing the components (81.3 g/100 g coconut milk, 8.1 g/100 g cane sugar, 10.2 g/100 g elderberry syrup, 0.4 g/100 g sunflower lecithin, inulin and LBG in above proportions), thorough blending and aeration. Simultaneously, a control sample (K) of ice cream without stabilizers was prepared.

2.3. Freezing process

Freezing was performed in an ice cream maker (Ariete Galatiera Compact, Italy) until the ice cream temperature was -6°C . Temperature was recorded at every minute interval (twice) using a temperature mini data logger (Kimo KT 20, Germany). On the basis of the recorded data the freezing curves were plotted and the cryoscopic temperature was determined using Microsoft Office Excel 2007 (Rahman et al., 2002). Then the samples were placed in plastic containers and hardened at -30°C for 24 h (chest deep freezer, Whirlpool, Poland).

2.4. Physicochemical analysis

Ice cream samples were stored at -30°C for 7 d before physicochemical analyses. Dry matter of ice cream was estimated by drying the samples at $130 \pm 1^{\circ}\text{C}$ for 3 h (AOAC, 2000). Fat content was determined according to AOAC (2000) using Soxhlet extractor, (Tecator Soxtec System HT 1043 extraction unit, Gemini, Apeldoorn) and protein content was assayed according to Kjeldahl method (AOAC, 2000). Ash content was analyzed according to PN-67/A-86430/Az2 (2002). Carbohydrates were calculated as the difference between 100% and the sum of the percentages of water, protein, total lipid (fat) and ash (US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory, 2016). All measurements were carried out in triplicate.

2.5. Determination of melting time, melting resistance and melting rate

In order to determine the melting time, a cooled metal ring in a form of a cone (stored at -30°C for 24 h; 35 mm in height, 35 mm in upper diameter, 25 mm in lower diameter, volume – 30 mL) was driven into a sample. In the following step, the ice cream samples were removed from a ring, transferred on a funnel with a mesh and then placed in a controlled temperature chamber at 25°C . The time required for the dripping of the first drop of melted ice cream was recorded (Jasińska, Trzciniński, Dmytrów, & Mituniewicz-Małek, 2012).

Melting resistance was determined according to the methodology employed by Silva Junior and Lannes (2011) modifying the sample size and melting time. It was determined by measuring the dripped volume for 45 min every 5 min since the samples were placed in a controlled temperature chamber. The data recorded were used to determine the melting rate (mL/min).

2.6. Ice cream overrun

The overrun of the final product was determined according to the following formula (1) (Ismail, Al-Saleh, & Metwalli, 2013):

$$\text{Overrun} = \frac{W_1 - W_2}{W_2} \cdot 100\% \quad (1)$$

where: W_1 – mass of unit volume of mixture (g), W_2 – mass of unit volume of ice cream (g).

2.7. Texture measurements

The evaluation of textural properties of ice cream: hardness and adhesiveness was performed in LFRA texture analyzer (Brookfield Engineering Laboratories, Inc., Middleboro, USA) using a penetration test and a chamber for backward extrusion. The chamber was filled with ice cream at temperature of -6°C . To ensure a constant temperature during measurement, a specially designed insulated container filled with ice was used. It was adapted to a Brookfield texture analyzer, which provided stabilization of thermal conditions. Temperature control during texture measurement was carried out using a 16-channel MPI-L digital temperature scanner (Metronic, Poland).

Hardness was defined as a maximal force (N) required to push a probe into the sample on a half of its height. Adhesiveness was determined on the basis of a force recorded during withdrawal of a probe from the sample. The following parameters were assumed for analysis: probe diameter – 12 mm, chamber diameter – 30 mm, probe rate during penetration – 0.2 mm/s, and pressure force – 0.2 N (Tiwari, Sharma, Kumar, & Kaur, 2015).

2.8. Colour determination

Colour of ice cream was determined using a colorimeter LOVIBOND CAM-SYSTEM 500 (The Tintometer Ltd., Amesbury, UK) and expressed in CIE – L^*a^*b system where L^* – lightness of ice cream (1–100), a^* – redness (+100) and greenness (–100), b^* – yellowness (+100) and blueness (–100). The measurements were performed in triplicate. The total colour difference (ΔE) was calculated using the equation below (2):

$$\Delta E = \sqrt{(L_{sample}^* - L_{control}^*)^2 + (a_{sample}^* - a_{control}^*)^2 + (b_{sample}^* - b_{control}^*)^2} \quad (2)$$

The values for background colours were: $L^* = 91.8$; $a^* = 0.4$; $b^* = -0.4$ (Tiwari et al., 2015).

2.9. Organoleptic evaluation

The organoleptic analysis of ice cream was carried out in laboratory conditions. The test participants were selected after previous pre-selection. Initially 30 people were subjected to the triangle test. The top 15 people were selected for the subsequent organoleptic test. The evaluation was carried out using the 5-point scale test. Distinctions of quality (colour, taste, smell, consistency) are presented in Table 1.

The number of points obtained in the sensory evaluation was analyzed and the level of ice cream quality was expressed in the following way: 5 – very good quality, 4 – good quality, 3 – sufficient quality, 2 – insufficient quality, 1 – bad quality.

2.10. Statistical analysis

All measured values were treated with Dean-Dixon test for identification and rejection of outliers. Values indicating gross error were rejected from further analyzes (Rorabacher, 1991). The test of Shapiro-Wilk was applied. In order to determine the effect of the addition of the stabilizer and its percentage concentration, the two-factor ANOVA test was used in a complete randomisation system. Further tests to detect the significance of differences between particular groups were found using the Student t -test applied to compare independent samples in pairs, and variance analysis (ANOVA) was used for more than two groups. Detailed analysis was based on Tukey's confidence intervals. The Pearson's correlation coefficients were used to evaluate linear

Table 1
Quality indicators and discriminants for sensory evaluation of ice cream.

Point scale	Quality discriminants with quality indicators			
	Consistency (0.3)	Taste (0.15)	Colour (0.15)	Smell (0.25)
5	Uniform, dense, creamy, ice crystals undetectable	Characteristic for the type of milk and additives used, intensive	Characteristic for the type of milk and additives used, intensive	Clear, aromatic, characteristic for ice cream of the chosen taste
4	Uniform, ice crystals barely detectable	Characteristic for the type of milk and additives used, less intensive	Characteristic for the type of milk and additives used, less intensive	Clear, aromatic, less adequate for ice cream of the chosen taste
3	Uniform, ice crystals detectable	Indistinct	Colour slightly changed	Indistinct, barely adequate for ice cream of the chosen taste
2	Uniform, large ice crystals visible and detectable	Hard to recognise	Colour clearly changed	Clearly changed
1	Uniform, large ice crystals visible and detectable	Unrecognizable	Unusual colour	Unusual, foreign

Table 2

Cryoscopic temperature of coconut milk-based ice cream with inulin and locust bean gum (LBG) addition.

Sample	Cryoscopic temperature T_{cr} (°C)
Control (K)	–2.5
Inulin 0.8 g/100 g	–2.5
Inulin 1.6 g/100 g	–2.7
Inulin 2.4 g/100 g	–2.9
Inulin 3.2 g/100 g	–2.9
Inulin 4.0 g/100 g	–3.0
LBG 0.2 g/100 g	–2.7
LBG 0.4 g/100 g	–2.9
LBG 0.6 g/100 g	–2.9
LBG 0.8 g/100 g	–3.0

relationships between variables. All statistical tests were carried out at significance level of $\alpha = 0.05$. Statistical processing of results was performed using R program version 3.1.2 and Statgraphics 5.0.

3. Results and discussion

3.1. Physicochemical characteristics of ice cream

One of the most important physical properties of food is the cryoscopic temperature. Because of its multidimensional importance it is extremely important to determine its value properly (Bogh-Sorensen, 2006; Kozłowicz & Kluza, 2012). The addition of both stabilizers to ice cream caused a variation in the cryoscopic temperature (Table 2). The values of T_{cr} determined based on analysis of the freezing curves were: –2.5 °C for the control (K) and –2.5 °C to –3.0 °C, and –2.7 °C to –3.0 °C, respectively, for ice cream with inulin and LBG. In this study a correlation between the amount of added stabilizer and the cryoscopic temperature of the ice cream was observed. The relationship between the amount of added stabilizer and the cryoscopic temperature was noted and then confirmed by Pearson's correlation coefficient. Its values for relationships between inulin content and T_{cr} and between LBG content and T_{cr} were, respectively, –0.948 and –0.923, indicating a strong negative correlation. Increasing contribution of the stabilizer corresponded to a drop in the cryoscopic temperature of ice cream. Muse and Hartel (2004), who studied ice creams produced with three types of sweetener and three different levels of emulsifier, noted cryoscopic temperatures ranging from –1.8 °C to –4.6 °C, whereas Alvarez, Wolters, Vodovotz, and Ji (2005) reported that T_{cr} ranged from –4.68 °C to –5.42 °C. According to the above authors, the resulting differences in the cryoscopic temperature did not affect the sensory evaluation of ice cream. The values of T_{cr} reported by Soukoulis et al. (2009) were –3.11 °C for ice cream containing 2 g/100 g of inulin and –1.78 °C for the samples with addition of 4 g/100 g of stabilizer. On the other hand, Aboufazi et al. (2015) noted the cryoscopic temperature of –4.9 °C for coconut milk ice cream. The T_{cr} values recorded in this

Table 3Chemical composition (mean \pm standard deviation, n = 3) of ice cream with inulin and locust bean gum (LBG) in the 100 g of final product.

Sample	Fat [g/100 g]	Protein [g/100 g]	Ash [g/100 g]	Dry matter [g/100 g]	Carbohydrates [g/100 g]
$\bar{x} \pm SD$					
Control (K)	20.78 \pm 0.74 ^a	2.20 \pm 0.002 ^{ab}	0.72 \pm 0.005 ^c	42.60 \pm 0.03 ^a	18.90 \pm 0.72 ^a
Inulin 0.8 g/100 g	20.83 \pm 0.79 ^a	2.23 \pm 0.02 ^{ab}	0.64 \pm 0.002 ^{bc}	43.72 \pm 0.11 ^{cd}	20.02 \pm 0.78 ^{ab}
Inulin 1.6 g/100 g	19.93 \pm 0.58 ^a	2.27 \pm 0.002 ^{ab}	0.63 \pm 0.003 ^{ab}	44.01 \pm 0.01 ^d	21.17 \pm 0.58 ^{ad}
Inulin 2.4 g/100 g	19.44 \pm 0.54 ^a	2.24 \pm 0.002 ^{ab}	0.71 \pm 0.008 ^e	45.27 \pm 0.15 ^f	22.88 \pm 0.56 ^{bd}
Inulin 3.2 g/100 g	20.03 \pm 1.09 ^a	2.19 \pm 0.005 ^{ab}	0.63 \pm 0.003 ^{ab}	46.29 \pm 0.10 ^g	23.44 \pm 1.11 ^{cd}
Inulin 4.0 g/100 g	19.91 \pm 0.67 ^a	2.23 \pm 0.002 ^{ab}	0.77 \pm 0.006 ^f	46.89 \pm 0.16 ^h	23.99 \pm 0.73 ^d
LBG 0.2 g/100 g	20.05 \pm 0.14 ^a	2.19 \pm 0.002 ^{ab}	0.64 \pm 0.007 ^d	43.02 \pm 0.08 ^b	20.14 \pm 0.08 ^{ab}
LBG 0.4 g/100 g	20.36 \pm 0.32 ^a	2.42 \pm 0.02 ^b	0.67 \pm 0.002 ^{bc}	43.57 \pm 0.08 ^c	20.11 \pm 0.30 ^{ab}
LBG 0.6 g/100 g	20.31 \pm 0.24 ^a	2.39 \pm 0.22 ^b	0.62 \pm 0.002 ^a	44.00 \pm 0.06 ^d	20.68 \pm 0.45 ^{abc}
LBG 0.8 g/100 g	21.93 \pm 1.74 ^a	2.10 \pm 0.003 ^a	0.65 \pm 0.004 ^c	44.58 \pm 0.08 ^e	19.90 \pm 1.66 ^a

^{a,b,c,d,e,f,g,h} Means in the same column denoted by different letters were significantly different (P value < 0.05).

study did not differ significantly from those reported by other authors including values obtained for ice cream produced from traditional milk (Alvarez et al., 2005; Muse & Hartel, 2004; Soukoulis et al., 2009). Although Aboulfazli et al. (2015) obtained T_{cr} lower by 2.4 °C as compared to the control sample in this study.

The composition of ice cream is presented in Table 3. As expected, the addition of inulin and LBG increased the dry matter content. It ranged from 42.6 g/100 g to 46.89 g/100 g. It was found that the addition of inulin (0.8 g/100 g) influenced this parameter to a lesser extent than the addition of the same amount of LBG. The highest content of dry matter was found in ice cream containing 4.0 g of inulin/100 g. The high proportion of fat in ice cream was due to the specificity of ingredients that were used to make ice cream e.g. coconut milk contained 21 g of fat in 100 mL of the product. However, significant changes in the content of carbohydrates in ice cream were associated with the increasing content of dry matter.

Based on the results of the ANOVA test, it was found that the type of stabilizer and its percentage share significantly differentiate the individual chemical parameters of the ice cream. The type of stabilizer used had the greatest influence on the ash content ($F = 235$ at $Pr = 9.06 \times 10^{-9}$) and the dry matter ($F = 319$ at $Pr = 1.78 \times 10^{-9}$). Only in the case of protein, the type of stabilizer had no effect on its content in ice cream ($F = 0.14$ at $Pr = 0.72$).

Melting is an important factor in assessing quality of ice cream, correctness of selected technology and freezing parameters. Melting time is determined by a number of factors such as: total solids, size of the ice crystals, size of the fat particles and their amount. Its value depends to a large extent on the composition of the mixture (Muse & Hartel, 2004). The shortest melting time – 16 min, was recorded for the sample with 4 g/100 g inulin, whereas the longest – 25 min for the control sample without stabilizers (Table 4). A strong negative correlation between inulin concentration and melting time (Pearson's

correlation coefficient was -0.89) was observed. The increased inulin content from 0 g/100 g–4 g/100 g was accompanied by reduced melting time. The highest melting resistance (22.5 mL), after 45 min, was observed for the sample with 4 g/100 g addition of inulin. However, there were no significant differences in this parameter between the control sample and samples with 1.6 g/100 g and 3.2 g/100 g addition of inulin. Similar results were reported by Isik, Boyacioglu, Capanoglu, and Erdil (2011). Appearance of the first drop in the control sample (without the addition of stabilizers) was observed after 13.5 min, whereas in the samples with 8 g/100 g, 6.5 g/100 g and 5 g/100 g of inulin, respectively, after 11.5 min, 10.8 min, and 8.5 min. The increase of inulin content in ice cream reduced the time of first drop, but increased melting resistance (Akalin & Erişir, 2008). Ice cream with LBG did not melt. This may be due to the high content of this stabilizer in the mixture in combination with coconut milk which is rich in polysaccharides. LBG forms a gel-like net inside the ice cream structure. It is recommended to add from 0.1 g/100 g–0.5 g/100 g of LBG to traditional ice creams containing animal protein (Cropper, Kocaoglu-Vurma, Tharp, & Harper, 2013).

The ice cream overrun ranged from 8.76% to 15.31% (Table 5). The type of stabilizer ($F = 9548.0$, $Pr < 2.2 \times 10^{-16}$) and its percentage share ($F = 8658.3$, $Pr < 2.2 \times 10^{-16}$) significantly differentiated the ice cream overrun. It was found that value of this parameter increased with increasing inulin content and decreased with increasing content of LBG. However, statistically significant differences were not found in the ice cream with inulin in the range of concentration from 1.6 g/100 g–4.0 g/100 g and LBG from 0.2 g/100 g–0.6 g/100 g. The lowest overrun was noted for the control (K) with no stabilizer added (8.76%). Akalin and Erişir (2008) also observed that the aeration level of ice cream with addition of 4 g/100 g of inulin was higher than for the control sample. The difference between results obtained for these samples was 53%, whereas in this study it was 43%. Tiwari et al. (2015)

Table 4Melting time, rate and resistance (mean \pm standard deviation, n = 3) of ice cream with inulin and locust bean gum (LBG).

Sample	Melting time	Melting rate (ml/min)					Melting resistance (ml)
	First drop (min)	After 25 min	After 30 min	After 35 min	After 40 min	After 45 min	After 45 min
$\bar{x} \pm SD$							
Control (K)	25.00 \pm 0.05 ^d	0.04 \pm 0.01 ^a	0.17 \pm 0.05 ^a	0.31 \pm 0.05 ^b	0.40 \pm 0.05 ^a	0.48 \pm 0.05 ^b	21.0 \pm 0.05 ^b
Inulin 0.8 g/100 g	20.00 \pm 0.05 ^c	0.04 \pm 0.01 ^a	0.22 \pm 0.05 ^c	0.29 \pm 0.05 ^a	0.40 \pm 0.05 ^a	0.44 \pm 0.05 ^a	20.0 \pm 0.05 ^a
Inulin 1.6 g/100 g	20.00 \pm 0.05 ^c	0.06 \pm 0.01 ^b	0.17 \pm 0.05 ^a	0.36 \pm 0.05 ^d	0.41 \pm 0.05 ^b	0.48 \pm 0.05 ^b	21.0 \pm 0.05 ^b
Inulin 2.4 g/100 g	19.00 \pm 0.05 ^b	0.12 \pm 0.01 ^c	0.23 \pm 0.05 ^d	0.34 \pm 0.05 ^c	0.43 \pm 0.05 ^c	0.48 \pm 0.05 ^b	21.5 \pm 0.05 ^c
Inulin 3.2 g/100 g	19.00 \pm 0.05 ^b	0.12 \pm 0.01 ^c	0.20 \pm 0.05 ^b	0.36 \pm 0.05 ^d	0.41 \pm 0.05 ^b	0.44 \pm 0.05 ^a	21.0 \pm 0.05 ^b
Inulin 4.0 g/100 g	16.00 \pm 0.05 ^a	0.16 \pm 0.01 ^d	0.27 \pm 0.05 ^e	0.37 \pm 0.05 ^e	0.45 \pm 0.05 ^d	0.50 \pm 0.05 ^c	22.5 \pm 0.05 ^d

^{a,b,c,d} Means in the same column denoted by different letters were significantly different (P value < 0.05).

Table 5
Hardness, adhesiveness and overrun (mean ± standard deviation, n = 3) of ice cream with inulin and locust bean gum (LBG).

Sample	Hardness (N)	Adhesiveness (Ns)	Overrun (%)
$\bar{x} \pm SD$			
Control (K)	2.41 ± 0.22 ^a	-1.69 ± 0.17 ^{bc}	8.76 ± 0.32 ^a
Inulin 0.8 g/100 g	2.60 ± 0.37 ^a	-2.22 ± 0.23 ^{ab}	10.92 ± 1.35 ^b
Inulin 1.6 g/100 g	2.65 ± 0.65 ^a	-1.60 ± 0.20 ^c	13.66 ± 0.16 ^{de}
Inulin 2.4 g/100 g	2.52 ± 0.69 ^a	-1.36 ± 0.13 ^c	13.88 ± 0.15 ^{de}
Inulin 3.2 g/100 g	2.44 ± 0.43 ^a	-1.80 ± 0.16 ^{bc}	14.45 ± 0.30 ^{de}
Inulin 4.0 g/100 g	2.92 ± 0.57 ^{ab}	-2.18 ± 0.22 ^{ab}	15.31 ± 0.56 ^e
LBG 0.2 g/100 g	4.21 ± 0.72 ^{bc}	-1.52 ± 0.10 ^c	13.51 ± 0.42 ^{ce}
LBG 0.4 g/100 g	4.58 ± 0.11 ^c	-1.50 ± 0.20 ^c	13.07 ± 0.17 ^{cd}
LBG 0.6 g/100 g	4.15 ± 0.69 ^{bc}	-2.44 ± 0.49 ^a	11.64 ± 0.69 ^{bc}
LBG 0.8 g/100 g	4.71 ± 1.14 ^c	-1.43 ± 0.27 ^c	9.96 ± 0.2 ^{ab}

^{a,b,c,d,e} Means in the same column denoted by different letters were significantly different (P value < 0.05).

Table 6
Colour values (mean ± standard deviation, n = 10) of ice cream with inulin and locust bean gum (LBG) (in fixed concentrations) after 48 h storage at -30 °C.

Sample	L*	a*	b*	ΔE
$\bar{x} \pm SD$				
Control (K)	69.40 ± 0.48 ^b	-3.39 ± 0.28 ^a	13.59 ± 0.67 ^a	-
Inulin 0.8 g/100 g	68.63 ± 0.52 ^a	-3.63 ± 0.30 ^a	13.70 ± 0.46 ^{bc}	0.81 ^c
Inulin 1.6 g/100 g	68.67 ± 0.58 ^a	-3.50 ± 0.56 ^a	13.57 ± 0.55 ^{ac}	0.74 ^b
Inulin 2.4 g/100 g	68.40 ± 0.33 ^a	-3.50 ± 0.36 ^a	13.70 ± 0.46 ^a	1.01 ^d
Inulin 3.2 g/100 g	68.40 ± 0.31 ^a	-3.63 ± 0.30 ^a	14.23 ± 0.38 ^{bf}	1.22 ^e
Inulin 4.0 g/100 g	68.13 ± 0.27 ^a	-3.63 ± 0.30 ^a	14.77 ± 0.38 ^{bdg}	1.75 ^e
LBG 0.2 g/100 g	67.77 ± 0.24 ^c	-4.43 ± 0.30 ^b	14.78 ± 0.38 ^{bc}	2.27 ^h
LBG 0.4 g/100 g	69.87 ± 0.27 ^{bd}	-3.50 ± 0.36 ^{ac}	12.68 ± 0.55 ^{adf}	1.02 ^d
LBG 0.6 g/100 g	68.93 ± 0.27 ^{bde}	-4.03 ± 0.38 ^b	15.03 ± 0.38 ^{bgh}	1.65 ^f
LBG 0.8 g/100 g	69.40 ± 0.80 ^{bd}	-4.03 ± 0.38 ^b	13.58 ± 0.83 ^{aei}	0.65 ^a

L* - lightness, a* - redness and greenness, b* - yellowness and blueness.
^{a,b,c,d,e,f,g,h} Means in the same column denoted by different letters were significantly different (P value < 0.05).

did not observe any change in the level of ice cream aeration in relation to the inulin content, while Mahdian and Karazhian (2013) reported its decrease by 33% (2 g/100 g inulin) and 16% (4 g/100 g inulin) in comparison to the control. Dłużewska et al. (2003) observed that the overrun of ice cream was inversely proportional to the LBG content in the mixture. In this study we obtained much lower values of this parameter than those presented in the available literature. Ice cream overrun depends to a great extent on the protein content in the mixture (Mahdian & Karazhian, 2013), so the low aeration of the mixture observed in this study was probably due to a total absence of animal protein and low protein content in coconut milk (2.2 g).

Hardness of ice cream is affected by many factors, including the overrun, ice crystal size, ice phase volume, and extent of fat destabilization. A product that contains more large ice crystals is characterized by higher hardness. Ice creams with low hardness (so-called creamy ice cream) contain small ice crystals (Muse & Hartel, 2004). The lowest hardness of 2.41 N was determined for the control ice cream. Addition of both stabilizers to the mixtures did significantly affect hardness of ice cream (two-factor ANOVA test - F = 6024.24; Pr < 2.2 × 10⁻¹⁶). Ice cream with LBG had higher hardness (4.15 N - 4.71 N) than the samples

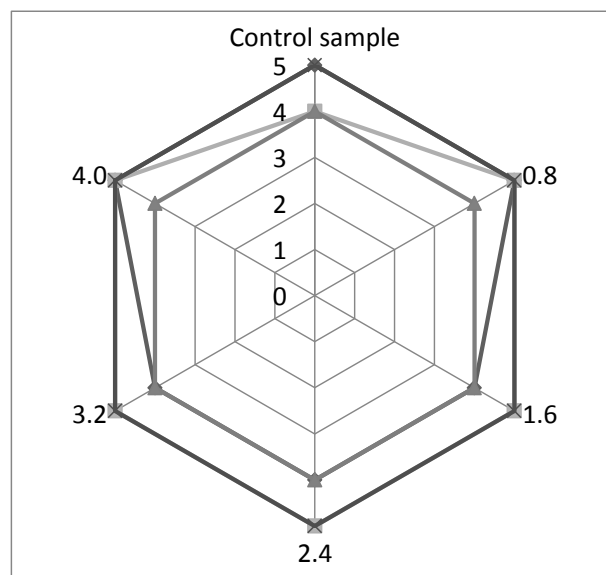


Fig. 1. Results of sensory evaluation of ice cream with inulin: (↔) consistency, (↔) taste, (↔) colour, (↔) smell.

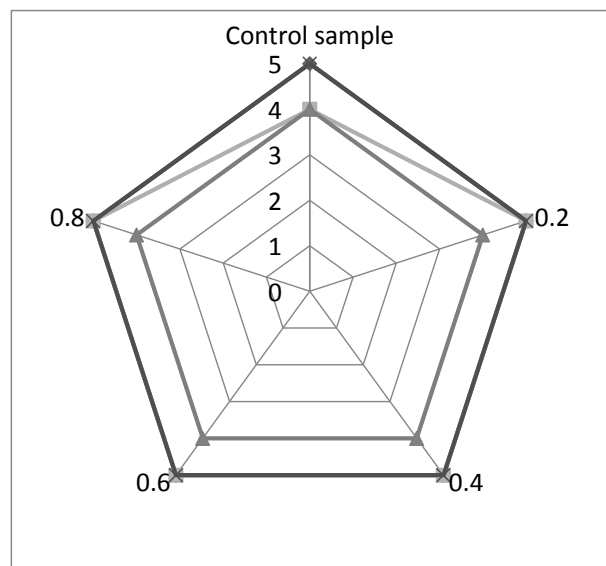


Fig. 2. Results of sensory evaluation of ice cream with LBG: (↔) consistency, (↔) taste, (↔) colour, (↔) smell.

with inulin (2.44 N- 2.92 N) (Table 5). There were slight differences in sample adhesion depending on the type of stabilizer used (in the two-factor ANOVA test - F = 16.88, Pr = 0.002) (Table 5). The lowest value of this parameter was found for ice cream with addition of 0.6 g/100 g LBG and 0.8 g/100 g inulin. The remaining samples were characterized by no statistically significant differences. Also, Akbari et al. (2016) did not observe statistically significant differences in hardness and adhesion of ice cream with 2, 3 and 4 g/100 g addition of inulin.

Colour of ice cream is one of the most important characteristics that affect customer choice. Its values and total difference (ΔE) in the examined ice cream are summarized in Table 6.

The stabilizer concentration had an effect on the L* parameter defining brightness (F = 5.30, Pr = 0.0007). The values of this parameter in ice cream with inulin (ranged from 68.13 to 68.67) were significantly lower than in the control sample (69.40). This means that the addition of inulin led to darkening of ice cream. The colour parameter a* ranged from -3.50 to -3.63, whereas the b* value was in the range from 13.57 to 14.77, and the lowest value was obtained for the

sample with 2.4 g/100 g of inulin, and the highest – for the one with 4 g/100 g inulin. The total colour difference ranged from 0.7 to 1.75. In the case of ice cream with LBG, the L^* value was the lowest for the sample with 0.6 g/100 g LBG and the highest – for the one with 0.2 g/100 g LBG. The control sample had the lowest a^* value, whereas the b^* value was in the range from 12.78 (0.4 g/100 g LBG) to 14.98 (0.6 g/100 g LBG). The statistically significant differences in ΔE were observed for ice cream containing both stabilizers (two factor ANOVA test – $F = 2980.3$; $Pr < 2.2 \times 10^{-16}$). According to the criteria adopted by the International Lighting Commission CIE (Heidelberg, 1999) absolute colour differences (ΔE) in the range from 0 to 2 are unrecognizable by the person experienced in distinguishing the colour. However, the observed differences in ice cream colour were lower than those found in the literature. Tiwari et al. (2015) obtained colour differences ranging from 3.6 to 7 in ice cream with variable inulin additions.

3.2. Organoleptic evaluation

Organoleptic assessment of food consists in determining its quality using the senses of smell, sight, taste and touch. This type of analysis is used primarily to assess non-measurable features and is conditioned by factors influencing consumers' perception and beliefs. Subjective organoleptic assessment depends primarily on the sensitivity of the evaluator and the conditions under which it is carried out (King & Arents, 1997). In the organoleptic assessment of the ice cream, such quality factors as consistency, taste, colour and smell were used. The control sample of ice cream was characterized by not too sweet taste and a uniform, not very soft consistency. In the testers' opinion, the addition of inulin and locust bean flour (in the whole range of shares used) caused that the ice cream had a better taste and a more creamy consistency, and they were rated higher by the consumers (Fig. 1, Fig. 2). Fuangpaiboon and Kijroongrojana (2015) reported that the addition of inulin to coconut ice cream did not alter the taste of ice cream compared to the control sample. They noticed, however, that the stabilizer addition had an effect on the sweetness of the ice cream and caused a noticeable change in their texture.

4. Conclusion

The ice cream obtained according to the recipe based on coconut milk with healthy additives and the chosen freezing technology, were characterized by physical characteristics similar to those of traditional products. Addition of the stabilizer influenced the cryoscopic temperature of ice cream. Both supplementation of the mixture with inulin and LBG resulted in a drop in the cryoscopic temperature of 0.5 °C.

Analysis of the chemical composition of the ice cream showed that the addition of inulin had a smaller effect on the increase in dry matter than the addition of the same amount of LBG. Ice-cream with coconut milk had high fat content, which resulted from the use of high-fat ingredients to make the mixture. The addition of stabilizers resulted in slight changes in the content of dry matter, ash, water and carbohydrates. The next parameters of the ice cream that are important for their quality are the melting time and the time of the first drop. The increased inulin content in the mixture reduced the time of the first drop during melting, but increased melting resistance of ice cream after 45 min. Ice cream with LBG did not melt, which was most probably due to too high concentration of stabilizer combined with polysaccharide-rich coconut milk.

Hardness, aeration, adhesiveness and colour are physical parameters that can be assessed instrumentally and which can also significantly affect the quality of ice cream. The addition of stabilizers influenced the hardness and aeration of ice cream and resulted in slight differences in their adhesiveness. The low overrun of the samples (from 8.76% to 15.31%) has been demonstrated, most probably due to the lack of animal products. Ice cream with LBG had higher hardness than the samples with inulin. Differences in the colour of individual ice

cream samples were statistically significant. The effect of the stabilizer type on the brightness of the ice was found. The addition of inulin led to darkening of the ice cream.

The statistically significant differences in ΔE were observed for ice cream containing both stabilizers. The observed differences in ice cream colour were lower than those found in the literature.

Non-measurable ice cream features were evaluated using organoleptic evaluation. The addition of stabilizers, regardless of their participation, caused the higher rating of ice cream by the testers. According to the testers they had a better taste and a more creamy consistency. This confirms the legitimacy of using stabilizers in the production of coconut milk ice cream. To summarize, it has been found that it is possible to obtain ice creams that do not contain animal products in their composition using a freezing technology similar to that used for traditional ice cream.

References

- Aboulfazli, F., Baba, A. S., & Misran, M. (2015). The rheology and physical properties of fermented probiotic ice creams made with dairy alternatives. *International Journal of Food Engineering*, 11, 493–504.
- Aboulfazli, F., Shori, A. B., & Baba, A. S. (2016). Effects of the replacement of cow milk with vegetable milk on probiotics and nutritional profile of fermented ice cream. *LWT-Food Science and Technology*, 70, 261–270.
- Agrawal, A. K. (2016). Effect of variation of ginger juice on some physical and sensory properties of ice cream. *Indian Journal of Dairy Science*, 69, 17–23.
- Akalin, A. S., & Erişir, D. (2008). Effects of inulin and oligofructose on the rheological characteristics and probiotic culture survival in low-fat probiotic ice cream. *Journal of Food Science*, 73, M184–M188.
- 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.
- Alvarez, V. B., Wolters, C. L., Vodovotz, Y., & Ji, T. (2005). Physical properties of ice cream containing milk protein concentrates. *Journal of Dairy Science*, 88, 862–871.
- AOAC International (2000). *Official methods of analysis of AOAC international* (17th ed.). Gaithersburg, MD, USA: Association of Analytical Communities.
- Barak, S., & Mudgil, D. (2014). Locust bean gum: Processing, properties and food applications—a review. *International Journal of Biological Macromolecules*, 66, 74–80.
- Bogh-Sorensen, L. (2006). *Recommendations for the processing and handling of frozen foods*. Denmark: International Institute of Refrigeration.
- Boye, J. I., Rajamohamed, S. H., & Britten, M. (2011). Processing foods free from dairy proteins. In J. I. Boye, & S. B. Godefroy (Eds.). *Allergen management in the food industry* (pp. 207–258). Hoboken, USA: John Wiley & Sons, Inc.
- Clark, S. (2012). *The science of ice cream* (2nd ed.). Cambridge: The Royal Society of Chemistry.
- Clark, S., Jung, S., & Lamsal, B. (2014). *Food Processing: Principles and applications* (2nd ed.). Chichester, UK: Wiley Blackwell.
- Cropper, S. L., Kocaoglu-Vurma, N. A., Tharp, B. W., & Harper, W. J. (2013). Effects of locust bean gum and mono- and diglyceride concentrations on particle size and melting rates of ice cream. *Journal of Food Science*, 78, C811–C816.
- Dłużewska, E., Gazda, B., & Leszczyński, K. (2003). Effect of some polysaccharide hydrocolloids on the quality of fruit ice concentrates. *Acta Scientiarum Polonorum Technologia Alimentaria*, 2, 97–107 (in polish).
- Euroglaces (2017) <http://www.euroglaces.eu/en/>, Accessed 15.03.17.
- Fuangpaiboon, N., & Kijroongrojana, K. (2015). Qualities and sensory characteristics of coconut milk ice cream containing different low glycemic index (GI) sweetener blends. *International Food Research Journal*, 22, 1138–1147.
- Heidelberg - Anonym (1999). *Colour and quality*. Kurfürsten-Anlage: Heidelberg Druckmaschinen AG52–60.
- Isik, U., Boyacioglu, D., Capanoglu, E., & Erdil, D. N. (2011). Frozen yogurt with added inulin and isomalt. *Journal of Dairy Science*, 94, 1647–1656.
- Ismail, E. A., Al-Saleh, A. A., & Metwalli, A. A. M. (2013). Effect of inulin supplementation on rheological properties of low-fat ice cream. *Life Science Journal*, 10, 1742–1746.
- Jasińska, M., Trzciniński, J., Dmytrów, I., & Mituniewicz-Malek, A. (2012). Whey protein concentrates and whey-fat preparations as powered milk substitutes in soft serve ice cream. *Acta Agrophysica*, 19, 37–50 (in Polish).
- King, B. M., & Arents, P. (1997). Measuring sources of error in sensory texture profiling of ice cream. In M. C. Gacula (Ed.). *Descriptive sensory analysis in practice* (pp. 201–217). Trumbull, USA: Food & Nutrition Press, Inc.
- Kong, F. K. (2009). Pilot clinical study on a proprietary elderberry extract: Efficacy in addressing influenza symptoms. *Online Journal of Pharmacology and Pharmacokinetics*, 5, 32–43.
- Kozłowiec, K., & Kluzka, F. (2012). Gel products properties influenced by freezing in different conditions. *International Journal of Refrigeration*, 35, 1715–1721.
- Lifschitz, C., & Szajewska, H. (2015). Cow's milk allergy: Evidence-based diagnosis and management for the practitioner. *European Journal of Pediatrics*, 174, 141–150.
- Lin, T. N. (2012). *Sensory analysis, instrumental analysis and consumers' acceptance toward multifunctional ice creams* PhD Thesis. University of Missouri-Columbia.
- Lopata, A. (2010). Allergenicity of food and impact of processing. In J. Ahmed, H. S. Ramaswamy, S. Kasapis, & J. I. Boyle (Eds.). *Novel food processing: Effects on*

- rheological and functional properties* (pp. 459–478). London: Taylor and Francis Group LLC.
- 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*, 1163–1174.
- Mattar, R., de Campos Mazo, D. F., & Carrilho, F. J. (2012). Lactose intolerance: Diagnosis, genetic, and clinical factors. *Clinical and Experimental Gastroenterology*, *5*, 113–121.
- Mikulic-Petkovsek, M., Ivancic, A., Schmitzer, V., Veberic, R., & Stampar, F. (2016). Comparison of major taste compounds and antioxidative properties of fruits and flowers of different *Sambucus* species and interspecific hybrids. *Food Chemistry*, *200*, 134–140.
- Misselwitz, B., Pohl, D., Frühauf, H., Fried, M., Vavricka, S. R., & Fox, M. (2013). Lactose malabsorption and intolerance: Pathogenesis, diagnosis and treatment. *United European Gastroenterology Journal*, *1*, 151–159.
- Muse, M. R., & Hartel, R. W. (2004). Ice cream structural elements that affect melting rate and hardness. *Journal of Dairy Science*, *87*, 1–10.
- PN-67/A-86430/Az2 (2002). *Milk and dairy products – ice cream – methods for chemical testing*. (in Polish).
- Protein Advisory Group (1972). *Guideline for the preparation of milk substitutes of vegetable protein*. PAG Guideline No. 13 Rome: Food and Agriculture Organization of the United Nations.
- Rahman, M. S., Guizani, N., Al-Khaseibi, M., Al-Hinai, S. A., Al-Maskri, S. S., & Al-Hamhami, K. (2002). Analysis of cooling curve to determine the end point of freezing. *Food Hydrocolloids*, *16*, 653–659.
- Rorabacher, D. B. (1991). Statistical treatment for rejection of deviant values: Critical values of Dixon's "Q" parameter and related subrange ratios at the 95% confidence level. *Analytical Chemistry*, *63*, 139–146.
- Sidor, A., & Gramza-Michałowska, A. (2015). Advanced research on the antioxidant and health benefit of elderberry (*Sambucus nigra*) in food—a review. *Journal of Functional Foods*, *18*, 941–958.
- Silva Junior, E. D., & Lannes, S. C. D. S. (2011). Effect of different sweetener blends and fat types on ice cream properties. *Food Science and Technology*, *31*, 217–220 (Campinas).
- Soukoulis, C., Fisk, I. D., & Bohn, T. (2014). Ice cream as a vehicle for incorporating health-promoting ingredients: Conceptualization and overview of quality and storage stability. *Comprehensive Reviews in Food Science and Food Safety*, *13*, 627–655.
- Soukoulis, C., Lebesi, D., & Tzia, C. (2009). Enrichment of ice cream with dietary fibre: Effects on rheological properties, ice crystallisation and glass transition phenomena. *Food Chemistry*, *115*, 665–671.
- Sridhar, R., Roopa, B. S., Varadaraj, M. C., & Vijayendra, S. V. N. (2015). Optimization of a novel coconut milk supplemented dahi—a fermented milk product of Indian sub-continent. *Journal of Food Science & Technology*, *52*, 7486–7492.
- Tiwari, A., Sharma, H. K., Kumar, N., & Kaur, M. (2015). The effect of inulin as a fat replacer on the quality of low-fat ice cream. *International Journal of Dairy Technology*, *68*, 374–380.
- US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory (2016). *USDA national nutrient database for standard reference, release 28. Version Current: May 2016*. <http://www.ars.usda.gov/ba/bhnrc/ndl> Accessed 15.03.17.
- Usai-Satta, P., Scarpa, M., Oppia, F., & Cabras, F. (2012). Lactose malabsorption and intolerance: What should be the best clinical management? *World Journal of Gastrointestinal Pharmacology and Therapeutics*, *3*, 29–33.
- Verhoeckx, K. C. M., Vissers, Y. M., Baumert, J. L., Faludi, R., Feys, M., Flanagan, S., et al. (2015). Food processing and allergenicity. *Food and Chemical Toxicology*, *80*, 223–240.
- Wichamane, Y., Acharaphan, M., & Santad, W. (2016). Effect of dragon fruit oligo-saccharide, stabilizer and sucrose on physical and sensory quality of ice cream. *International Food Research Journal*, *23*, 269–276.
- Yuliana, N., Rangga, A., & Rakhmiati (2010). Manufacture of fermented coco milk-drink containing lactic acid bacteria cultures. *African Journal of Food Science*, *4*, 558–562.