OPEN ACCESS International Journal of Dairy Science

ISSN 1811-9743
DOI: 10.3923/ijds.2020.XX.XX

Research Article

Physical Properties and Microstructure of Ice Cream Supplemented With Minor Components of Wheat Germ Oil

[1,3]Sameh S. El-Hadad, [1]Natali A. Tikhomirova, [2]Antonina A. Tvorogova, [2]Tatiana V. Shobanova and [3]Mahmoud Abd El-Aziz

[1]Department of Technical and Biotechnology of Food Products of Animal Origin, Moscow State University of Food Production, 125080, 11, Volokolamskoye Street, Moscow, Russia
[2]All-Russian Scientific Research Institute of Refrigeration Industry-Branch of V.M. Gorbatov Federal Research Center for Food Systems of RAS, 12, Kostyakova Street, Moscow, 127422, Russia
[3]Department of Dairy, Food Industries and Nutrition Division, National Research Centre, El-Buhouth Street, Dokki, Giza, Egypt

Abstract

Background and Objective: Vegetable oils contain a wide range of bioactive minor components. Minor components are of great interest because they have many health benefits and affect the technical properties of oils and fats as well as can affect the physical and structural properties of some foods. The effect of using wheat germ oil extract, as bioactive minor components of Wheat Germ Oil Extract (WGOE), on some physical and structural properties of ice cream was evaluated. **Materials and Methods:** Ice cream mixes were supplemented with WGOE at rate 0.5, 1.0, 1.5, 2.0 and 3.0%, while the control mix was not fortified. The pH and dynamic viscosity of ice cream mix as well as overrun, air cell size, ice crystal size, melting resistance, dimensional stability and sensory properties of ice cream were determined. **Results:** The pH decreased, but viscosity sharply increased as the concentration of WGOE increased. The overrun was not significantly affect by WGOE addition, up to 1.0% and thereafter decreased on further addition. The addition of WGOE also increased the air cell sizes and melting rate, while decreased the ice crystal sizes and dimensional stability of ice creams compared to the control sample. There were no differences in the sensory scores of the ice cream containing WGOE, up to 1.0%, compared to the control sample, but slightly decreased with further addition. **Conclusion:** The addition of the WGOE as bioactive minor components, up to 1.0%, may positively affect the physical and structure of the ice cream; increase mix viscosity, increase air cell sizes and decrease crystal sizes.

Key words: Ice cream, minor components, microstructure, air cell size, ice crystal size, dimensional stability

Citation: El-Hadad, S.S., N.A. Tikhomirova, A.A. Tvorogova, T.V. Shobanova and M.A. El-Aziz, 2020. Physical properties and microstructure of ice cream supplemented with minor components of wheat germ oil. Int. J. Dairy Sci., 15: XX-XX.

Corresponding Author: Mahmoud Abd El-Aziz, Department of Dairy, Food Industries and Nutrition Division, National Research Centre, El-Buhouth Street, Dokki, Giza, Egypt

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Ice cream is a complex food colloid that includes the unfrozen phase of the serum, fat globules, ice crystals and air bubbles. The fat globules are covered with a layer of protein/emulsifier and the air cells are partially covered with fat globules. The serum phase contains high molecular weight polysaccharides and sugars in the form of a freeze dried concentrated solution[1]. A typical ice cream composition consists of four main parts: 50% air cells, 30% ice crystals, 5% fat and 15% sugar solution (by volume). Ice crystals, fat globules and air cells are suspended in a liquid phase called a matrix[2]. However, ice cream is rich in calories because it contains a high percentage of carbohydrates, protein and fats, but it is poor in natural antioxidants, dietary fiber, vitamins and some minerals[3]. Recently, several technological developments have taken place in the way ice cream is produced. These developments are largely driven by consumer factors, such as the desire for health products (low-calorie products and products supplemented with probiotics, antioxidants, phytosterols, phospholipids, vitamins, minerals, etc.) and the need for innovation to generate new interest and differentiation in the market[4-5].

Vegetable oils are mainly composed of triacylglycerols, but they also contain a wide range of minor components, including sterols, tocopherols, carotenoids, phenolic compounds, diacylglycerols, monoacylglycerols, free fatty acids, phospholipids and minerals[6]. Minor lipid components are of interest because they affect the physical and chemical properties of the oils, possibly provide health benefits and might be used for the authentication of different oils and their mixtures[7]. Wheat germ oil is rich in minor components such as non-polar lipids, glycolipids, phospholipids, phytosterols, pigments and volatile components. It is also rich in tocopherols, particularly α-tocopherol and β-tocopherol, which gives it various health benefits. Wheat germ oil is used in medicine, agriculture and the food industry. Some of its applications include the production of vitamins and nutritional supplements[8-9]. Bikheet *et al.*[10] supplemented ice milk with natural bioactive components from Roselle calyces and cinnamon extracts. Sagdic *et al.*[11] investigated the effect of ellagic acid, gallic acid, grape seed extract, pomegranate peel extract and peppermint essential oil supplementation as bioactive components on sensorial and antioxidative properties of ice cream.

There are many studies on improving physical properties nutritional value and health benefits of ice cream by supplementing with fruits, juices, spices, herbs, probiotic bacteria, oils, mucilage and bioactive components[11-17]. However, there is no information on the use of concentrated minor components in the production of ice cream as a portion of functional dairy food. With the increasing interest in producing healthy or high-quality products by adding ingredients that have health and nutritional benefits, food workers are interested in studying the effect of these additives on physical and sensory properties, in addition to studying the interactions of those additives with the main components. Therefore, this study aimed to investigate the possibility of producing ice cream as a functional dairy food using bioactive minor components of wheat germ oil and evaluate some physical, structure and sensory properties of resultant ice cream.

MATERIALS AND METHODS

Materials: Skim milk powder (C JSC, Alekseevsky Dairy Canning Plant, Belgorod region, Russia), butter at 72.5% (OJSC, Rogachevsky Dairy Canning Plant, Belarus), commercial-grade granulated sucrose, wheat germ oil (Sampo Company, Russia) and vanilla favor (Boehringer Manheim GMB, Germany) purchased from the local market at Moscow, Russia. Stabilizer, Cremodan 334, was provided by DuPont-Danisco, Company Russia.

Methods: This study was conducted at Moscow State University of Food Production and All-Russian Scientific Research Institute of Refrigeration Industry (Moscow, Russia), during the period from October 2019 to January 2020.

Preparation of minor components extract: The minor components of wheat germ oil were extracted using hexane/methanol system, as described by Miraliakbari and Shahidi[18]. In 500 mL separator funnel, 20 g of oil was mixed with 200 mL of hexane, 100 mL of methanol was added to the mixture, sealed and then agitated for 5 min with periodic venting. The separator funnel was then sealed with nitrogen and stored at 4°C for 1 h. The methanol fraction was decanted into a 1 L round flask. The extraction process was repeated 4 times and the pooled methanol extracts were evaporated in a rotary vacuum evaporator (Rotavapor R110, Buchi, Switzerland) at 50°C. The wheat germ oil extract (WGOE) was stored at -80°C until used within a maximum period of one week. Some minor components, measured by HPLC, in the WGOE are shown in Table 1.

Ice cream making: Ice cream mixes were formulated separately in 2 kg batches to contain 10.0% fat, 15.0% sugar, 11.5% MSNF and 0.5% Cremodan 334 as a stabilizer. The

Table 1: Some minor components in the wheat germ oil extract

Items	mg/100 g
α-tocopherol	17.28
γ-tocopherol	18.10
Cholesterol	21.85
β-sitosterol	884.95
Stigmasterol	667.49
Ergosterol	30.36

WGOE was added to mixes at a rate of 0.5, 1.0, 1.5, 2.0 and 3.0% to create 5 experimental mixes. The control mix was formulated to contain the same amount of fat, sugar, MSNF and stabilizer but without WGOE. After blending the wet and dry ingredients, the mix was homogenized at 65°C using a laboratory homogenizer (Rannie, Copenhagen, Denmark) at 13.6 MPa and 3.5 MPa in a two-stage process, pasteurized at 81°C, cooled and aged overnight at 5°C. Just before freezing in a batch freezer (Carpigiani LABO 8 12 E Batch Freezers, Russia) for 12 min, vanilla was added to flavor the mix at a usage level of 0.1% (wt/wt). The resultant ice cream was poured into 250 mL PVC cups, covered and hardened in a deep freezer at -25°C for 24 hrs before analysis. Three replicates were done for each batch.

Analysis of ice cream mixes

Acidity and pH: Calibrated pH-meter (HANNA Instruments, pH 211, Italy), with a glass electrode, was used for directly measuring the pH value of the ice cream mixes. Acidity content, expressed as percentage lactic acid, was determined by using 0.10 N NaOH to the phenolphthalein end point[19].

Dynamic viscosity: The dynamic viscosity of the ice cream mixes was measured using a Brookfield DV-II+ Pro Programmable Viscometer (Brookfield Engineering Laboratories, INC. Middleboro, MA 02346-1031, USA) with a measuring spindle SC4-31 at 4 rpm after aging. The ice cream mix was poured into a 10 cm^3 metal cylinder and the viscosity was measured at 5°C. Each result was then recorded in triplicates in mPa.s after 30 sec rotation.

Overrun: Overrun was calculated for all ice cream samples using the weight-volume method as described by Daw and Hartel[20]. A volume of ice cream mix was weighed before freezing and the same volume of ice cream was weighed after freezing. Overrun was calculated using the following equation:

$$\text{Overrun}\ (\%) = \frac{\text{Weight of mix} - \text{Weight of ice cream}}{\text{Weight of ice cream}} \times 100$$

Air cell size distribution: Air cell sizes were measured using an OLYMPUS CX41 microscope (Japan) with a built-in camera according to the method of Chang and Hartel[21]. A temperature-controlled, refrigerated was set at (-6°C) for measurements. A small amount (0.2-0.5 mL) of ice cream was carefully placed in the depression on the slide and covered with a coverslip. Air bubbles were displayed at the surface of the coverslip. No dispersing liquid was needed. At least two slides of each sample were prepared and approximately four images were taken for air cells. The studies were carried out at an increase of 100 times. The research results were processed using the Image Scope M program.

Ice crystal size distribution: The dispersion of ice crystals was determined according to the method developed at the All-Russian Research Institute of Scientific Research[22]. For this, an Olympus Cx41 microscope connected to a PC with software was used.

Melting resistance: Melting resistance of ice cream samples was carried out according to the method of Goff and Hartel[2]. Ice cream samples (250 mL) stored at -25°C were weight and prepared by carefully cutting the PVC cups and left to melt into a plastic container below a mesh screen at 20±1°C. After 60 min, the weight of the melted ice cream was recorded every 10 min for 120 min. Melting resistance was calculated as the weight of ice cream melt/weight of ice cream before melting x100. Melting rates were calculated by determining the equation for the linear portion of the melting data (from 60 to 120 min) according to Alvarez *et al.*[23]

The dimensional stability: A sample of frozen ice cream was taken from a metal sample previously aged for at least 5 hrs at a temperature of -20°C, placed in a Petri dish and then in a thermostat with a temperature of 20±1°C. Immediately after installation in the thermostat, the sample was photographed every 10 min.

Sensory analysis: The sensory analysis of ice cream samples were carried out at the laboratory of All Russian Scientific Research Institute of Refrigeration Industry-Branch of V.M. Gorbatov, Research Center for Food Systems RAS 12, Moscow, Russian. Eleven trained judges (males and females) were selected to evaluate appearance, body and structure and aroma and taste on a scale of 1, 3 and 6 points, respectively[24]. Ice cream samples of 25-30 g were served to the judges in a special ice cream cups at a serving temperature of 10°C.

Statistical analysis: The obtained data were performed in triplicate and were analyzed using the SAS software program version 9.1[25]. Analysis of variance (One Way-ANOVA) and Duncan's multiple range tests was used to determine the differences between treatment means. Statistical significance was tested at the 5% level.

RESULTS AND DISCUSSION

Ice cream mix properties: Acidity, pH and dynamic viscosity of ice cream mixes containing different concentrations of the wheat germ oil extract (WGOE), as bioactive minor components, are presented in Table 2. The addition of WGOE caused a slight ($p>0.05$) increase in acidity and a decrease in the pH of the ice cream mixes, due to the presence of some free fatty acids and interaction between phenolic compounds in the WGOE with milk proteins[12,26]. Sagdic *et al.*[11] reported that the addition of some phenolic compounds caused a decrease in pH value due to the acidic nature of phenolic compounds. Fernandez-Orozco *et al.*[27] reported that the most abundant phenolic acids in wheat bran are derivatives of hydroxycinnamic acids, specifically ferulic acid, dehydrodimers and dehydrotrimers of ferulic acid and sinapic and p-coumaric acids. The decrease in pH value was significant ($p>0.05$) in ice cream mixes containing $\geq$1.0% WGOE compared to the control mix, however, pH values in mixes with different concentrations of WGOE showed similarity in between. A similar trend was found by Zhu *et al.*[28] in wheat starch-phenolic compound suspension. Some phenolic acids significantly lowered pH to 2.95-4.25, compared with control (pH 6.79). The acidity and pH of all ice cream mixes were also within the normal range reported by Bajad *et al.*[29], Gabbi *et al.*[13] and Naeem *et al.*[12].

In general, all ice cream mixes containing WGOE were significantly more viscous ($p<0.05$) than the control mix (Table 2). The viscosity gradually increases ($p\leq0.05$) from 1057±61 to 2913±61 mPa.s, as the added WGOE increased from 0.0 to 3.0%. The high mix viscosities in WGOE mixes can be related to the presence of some minor components such as monoglycerides, diglycerides, phospholipids and phenolic compounds in the WGOE that can bind with water. Syed *et al.*[30] reported that binding of water with emulsifiers caused viscosity enhancement, which in turn increased the flow time. Additionally, the viscosity is more affected by the number and position of hydroxyl and methoxy groups of phenolic compounds. Similar, phenolic compounds increased rheological properties of both wheat starch and whey protein suspensions due to structural features of the phenolic compounds[28,31]. Such an effect was also found by Guler-Akin *et al.*[14] in mixes supplemented with 1.0% carob extract.

Ice cream properties

Overrun: Figure 1 shows the overrun percentage of the ice cream samples when supplemented with different concentrations of WGOE. The highest mean overrun percentage was determined in the ice cream sample containing 1.0% WGOE, followed by that containing 0.5% WGOE and control sample, but the differences among them were not significant statistically ($p>0.05$). The slight increase in the overrun could be due to the addition of WGOE, up to 1.0%, improving the viscosity of the mixture, which created stable foam[12]. However, when adding the WGOE at high concentrations, >1.0%, a significant decrease in the percentage of overrun was observed ($p<0.05$). A similar trend was found by Salem *et al.*[8] on a study about the red grape pomace extract added ice cream. The decrease in overrun at high concentrations of WGOE may be related to the high mix viscosity, which weakening air incorporation[29,32]. The high mix viscosity also caused shear force increase during freezing, promoting fat globule interactions and fat coalescence[33]. The raise of fat coalescence leads to the formation of thin lamellae

Table 2: Acidity, pH and dynamic viscosity of ice cream mix supplemented with different concentrations of wheat germ oil extract after aging at 5°C

Ice cream mixes	pH	Acidity (%)	Dynamic viscosity (mPa.s)
Control	6.59±0.010[a]	0.20±0.007[a]	1057±61[e]
0.5% WGOE	6.55±0.014[ab]	0.21±0.005[a]	1640±48[d]
1.0% WGOE	6.54±0.021[b]	0.22±0.014[a]	2357±58[c]
1.5% WGOE	6.53±0.010[b]	0.23±0.006[a]	2420±90[c]
2.0% WGOE	6.53±0.012[b]	0.23±0.010[a]	2603±55[b]
3.0% WGOE	6.51±0.007[b]	0.24±0.016[a]	2913±85[a]

Means (n = 3 ±SD) with same letters in the same column are not significantly different ($p<0.05$); WGOE, wheat germ oil extract

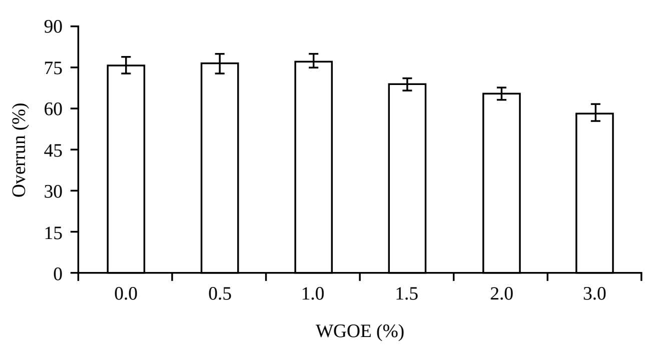

Fig. 1: Mean overrun percentage of ice cream samples supplemented with different concentrations of the wheat germ oil extract (WGOE)

between air cells, which may ultimately destabilize the film and break the air cells[34]. Additionally, WGOE at high concentrations may increase the displacement of protein on the fat globule surface, accelerating fat destabilization and decrease the overrun[2].

Air cell size: The effect of adding different concentrations of WGOE on the mean air cell size of ice cream is shown in Fig. 2a-f and Table 3. In general, the mean air cell size was larger in ice cream samples containing WGOE (30-37 µm) than the control sample (26 µm). The mean air cell size of ice cream

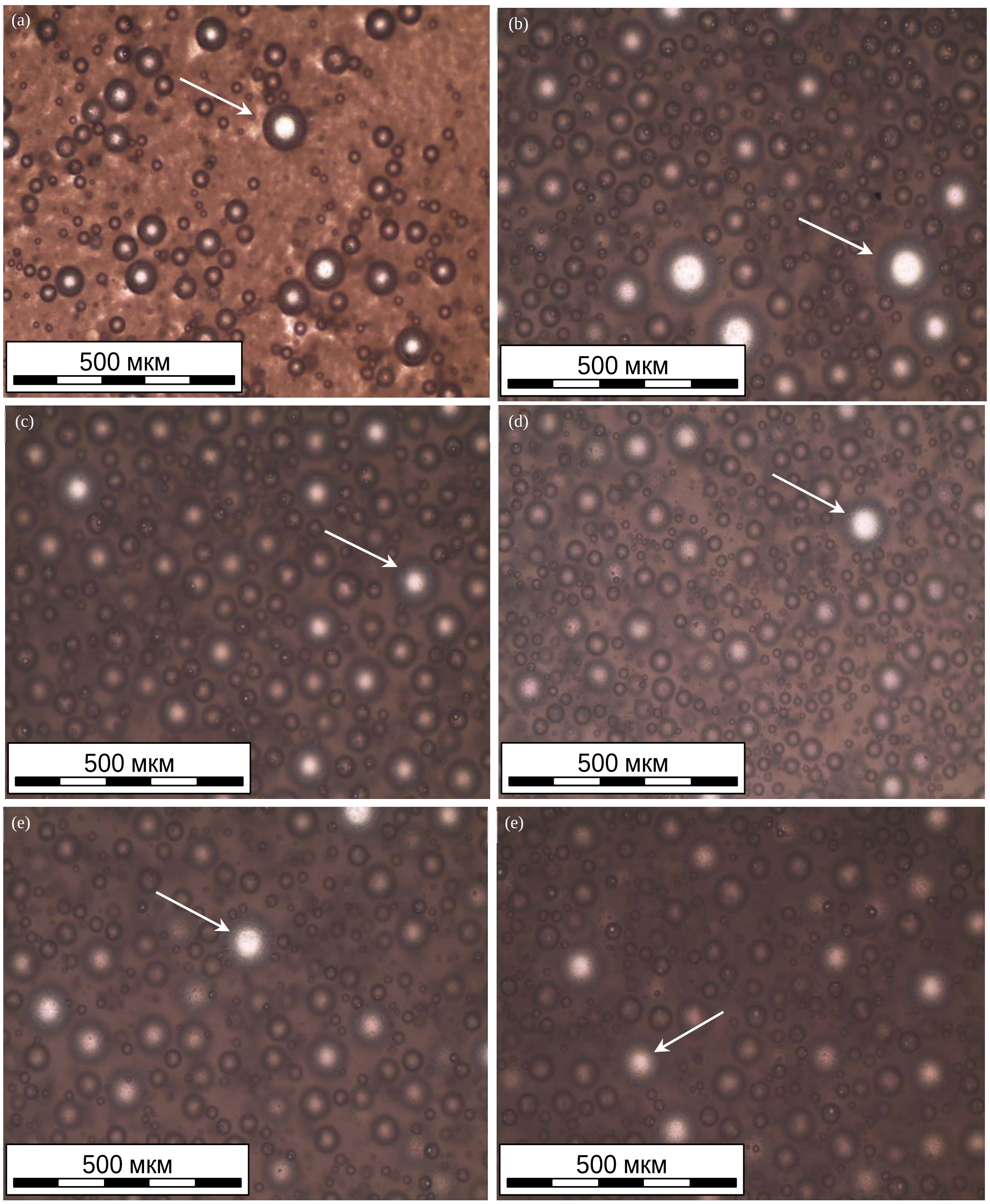

Fig 2(a-f): Microscope images of air cell size of ice cream samples supplemented with different concentrations of the wheat germ oil extract (WGOE) after 1 day of storage at -25°C, (a) Control sample without WGOE, (b) Sample supplemented with 0.5% WGOE, (c) Sample supplemented with 1.0% WGOE, (d) Sample supplemented with 1.5% WGOE, (e) Sample supplemented with 2.0% WGOE, (f) Sample supplemented with 3.0% WGOE, →: Arow point to air cell

Table 3: Mean air cell sizes of ice cream samples supplemented with different concentrations of the wheat germ oil extract

Ice cream samples	Mean air cell sizes (µm)		Ice crystal size (µm)
	After 1 day	After 90 days	
Control	26.0	25.0	32.0
0.5% WGOE	34.0	33.0	32.0
1.0% WGOE	37.0	37.0	30.0
1.5% WGOE	30.0	30.0	29.0
2.0% WGOE	32.0	31.0	27.0
3.0% WGOE	30.0	29.0	26.0

WGOE: Wheat germ oil extract

samples increasing from 26 to 37 µm as WGOE increased from 0 to 1.0%. Above 1.0% WGOE, the mean air cell size decreased to 30-32 µm on further addition, due to the highest viscosities and the highest shear stresses, which breaks down the air cells[35], but was still higher than the control sample. On the contrary, Sofjan and Hartel[36] and Warren and Hartel[37] found that increasing overrun decreased the mean air cell size. This trend was not seen in the ice cream sample containing WGOE. For example, ice cream samples containing 1.0% WGOE, which had the highest overrun, had also the highest mean air cell size (37 µm). Also, the mean air cell size of the ice cream sample containing 3.0% WGOE was higher (30 µm) than the control sample (26 µm), although it has a lower overrun. In this respect, it can be said that adding the WGOE at a low concentration ($\leq$1.0%) can act as an emulsifier, which helps to stabilize the air cell interface and prevent air cell breakdown[37]. El-Rahman *et al.*[38] reported that emulsifiers caused the agglomeration of fat which in turn finely dispersed and stabilized the air cells. Therefore, these results suggest that the breakdown or stabilization of air cells depends on more than one factor during freezing.

Over the storage period (-25°C) of 90 days, some air cells in ice cream samples appeared larger than those measured one day after hardening (Fig 3a-f). This finding is consistent with that found by Park *et al.*[39], who found that the air cell size increases with long storage time. Additionally, Sofjan and Hartel[36] reported that air cells tend to coalesce into larger cells during storage, especially at temperatures higher than -25°C. However, there was no much difference in the mean air cell size of ice cream samples (Table 3). The mean air cell size slightly decreased in the control sample and ice cream samples containing 0.5, 2.0 and 3.0% WGOE but was more stable in ice cream samples containing 1.0 and 1.5% WGOE as the storage of the period increased.

Ice crystal size: As seen in Table 3 and Fig. 4a-f, the mean ice crystal size ranged from 26.0 to 32.0 µm across different concentrations of WGOE. The mean size of the ice crystals was in the range mentioned by Muse and Hartel[35], but it was lower than that mentioned by Park *et al.*[39]. The ice crystals in the control sample were the largest, while these in the ice cream sample containing 3.0% WGOE were the smallest. Ice crystal size gradually decreased with increasing the concentration of the WGOE. Increasing the concentration of the WGOE leads to an increase in dynamic viscosity, which in turn leads to a decrease in the growth of ice crystals[33,40]. Schmidt and Smith[41] mentioned that an increase in viscosity may inhibit the development of iciness in frozen dairy dessert. This owing to the concentration of the unfrozen phase in the lamellae may increase sufficiently to decrease the movement of water molecules and thus, limit ice crystal growth. Kamal-Eldin[7] has reported that minor lipids can influence nucleation by increasing sites for nucleation, changing temperature at which nucleation occurs, or interfering with nuclei formation. Minor lipids can affect the rate of crystal growth, either retarding or accelerating it until the system reaches equilibrium. Therefore, WGOE, as bioactive minor components, are emerging as new options to limit ice crystal growth and recrystallization.

Melting resistance and dimensional stability: The melting resistance of ice cream as affected by the addition of WGOE is depicted in Fig. 5. In general, ice creams made with WGOE had the fastest melting rate ($p<0.05$) compared to control sample. The melting rate gradually increased as the concentration of the WGOE increase. Bajad *et al.*[29] and Muse and Hartel[35] reported that a decrease in the melting rate as an overrun increased. The larger volumes of air present in high overrun products caused a reduced rate of heat transfer, which resulted in slower melting rates[39]. This trend was not seen in ice cream samples containing WGOE, up to 1.0%, which had an overrun $\geq$that of the control sample. However, this trend may compatible with ice cream samples containing >1.0% WGOE, which had the lowest overrun. Other authors, however, reported that as a viscosity of ice cream mix increased, the partial coalescence increases and the melting rate decreases[29,32,33]. This same trend was also not seen in ice cream samples that had high viscosity. The dimensional stability of the control sample was more stable than that containing WGOE during the melting at 20°C for 100 mim; the dimensional stability decreased as the WGOE increases (Fig. 6a-d). These results confirm the above results of the meltdown test (Fig. 5). This means that adding the WGOE may change the physical properties of milk fat, e.g., reduce solid fat

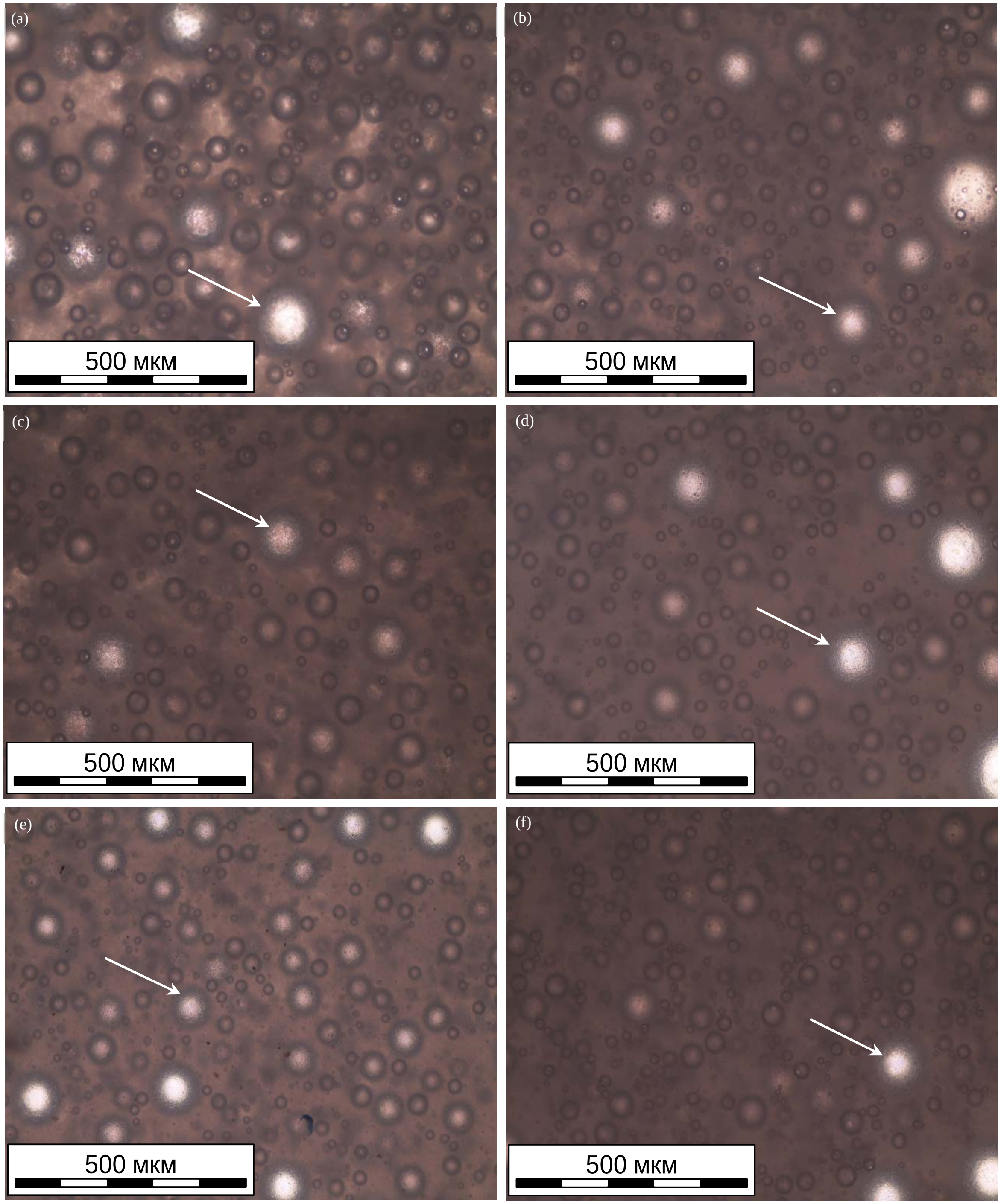

Fig 3(a-f): Microscope images of air cell size of ice cream samples supplemented with different concentrations of the wheat germ oil extract (WGOE) after 90 days of storage at -25°C, (a) Control sample without WGOE, (b) Sample supplemented with 0.5% WGOE, (c) Sample supplemented with 1.0% WGOE, (d) Sample supplemented with 1.5% WGOE, (e) Sample supplemented with 2.0% WGOE, (f) Sample supplemented with 3.0% WGOE, →: Arow point to air cell

content. Abd El-Aziz *et al.*[42] found that adding palm oil to butter oil resulted in a decrease in the solid fat content of the mixture at 0-10°C compared to both oils separately. Minor components when added to fat can affect crystallization; nucleation, crystal growth and polymorphism[43]. Although there are clear differences in the melting rate and dimensional

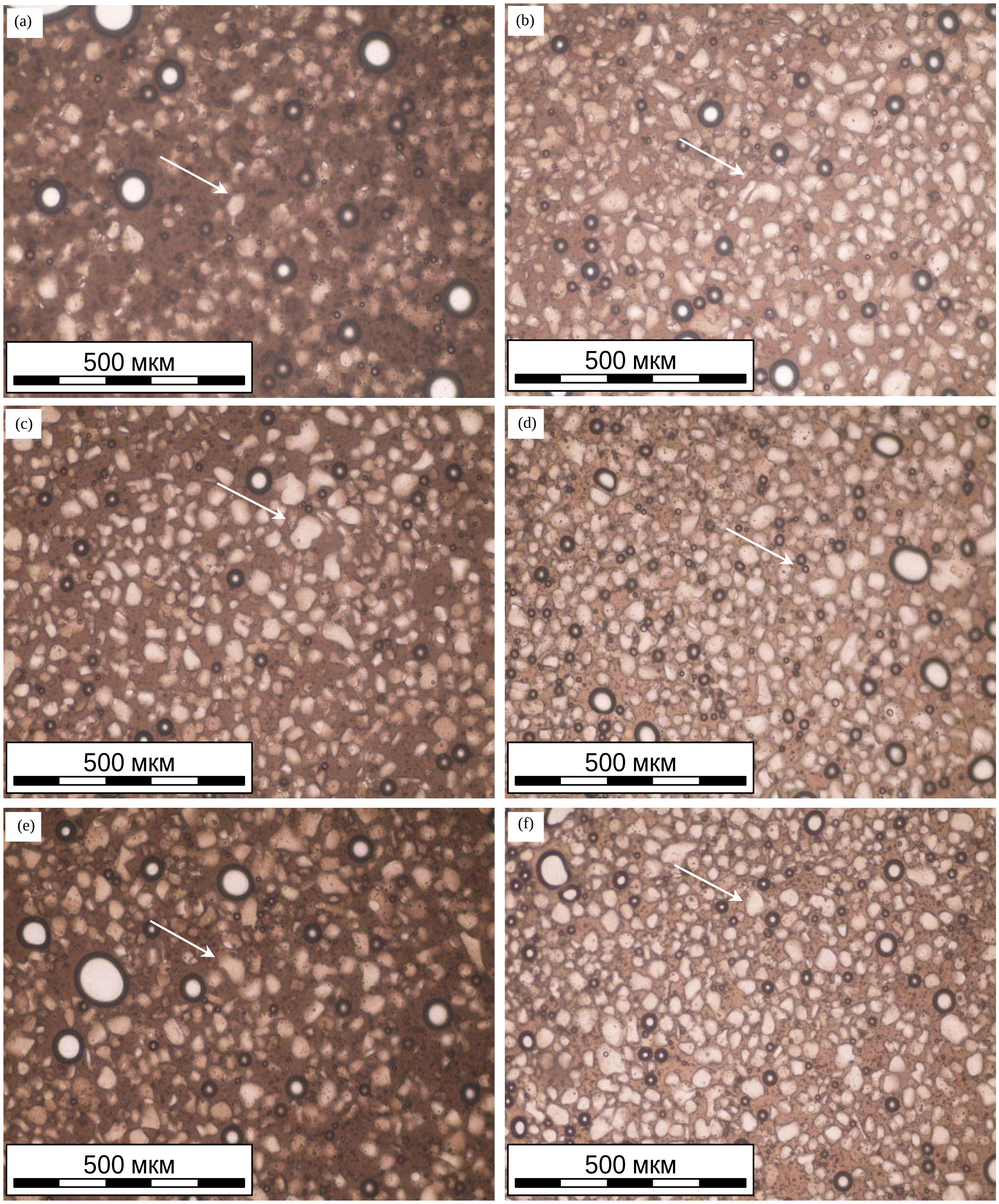

Fig. 4(a-f): Microscope images ice crystal sizes of ice cream samples supplemented with different concentrations of the wheat germ oil extract (WGOE) after 90 days of storage at -25°C, (a) Control sample without WGOE, (b) Sample supplemented with 0.5% WGOE, (c) Sample supplemented with 1.0% WGOE, (d) Sample supplemented with 1.5% WGOE, (e) Sample supplemented with 2.0% WGOE, (f) Sample supplemented with 3.0% WGOE, →: Arow point to ice crystal

stability, there are no clear differences in the properties of melted ice cream, such as smoothness, foam and fat clusters. Therefore, the components of the WGOE may have a negative effect on the melting rate more than the positive effect of the overrun, viscosity and partial coalescence of ice cream.

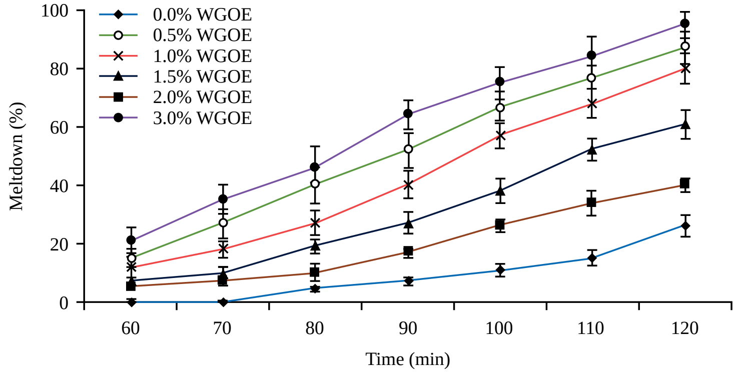

Fig. 5: Meltdown of ice cream samples supplemented with different concentrations of the Wheat Germ Oil Extract (WGOE)

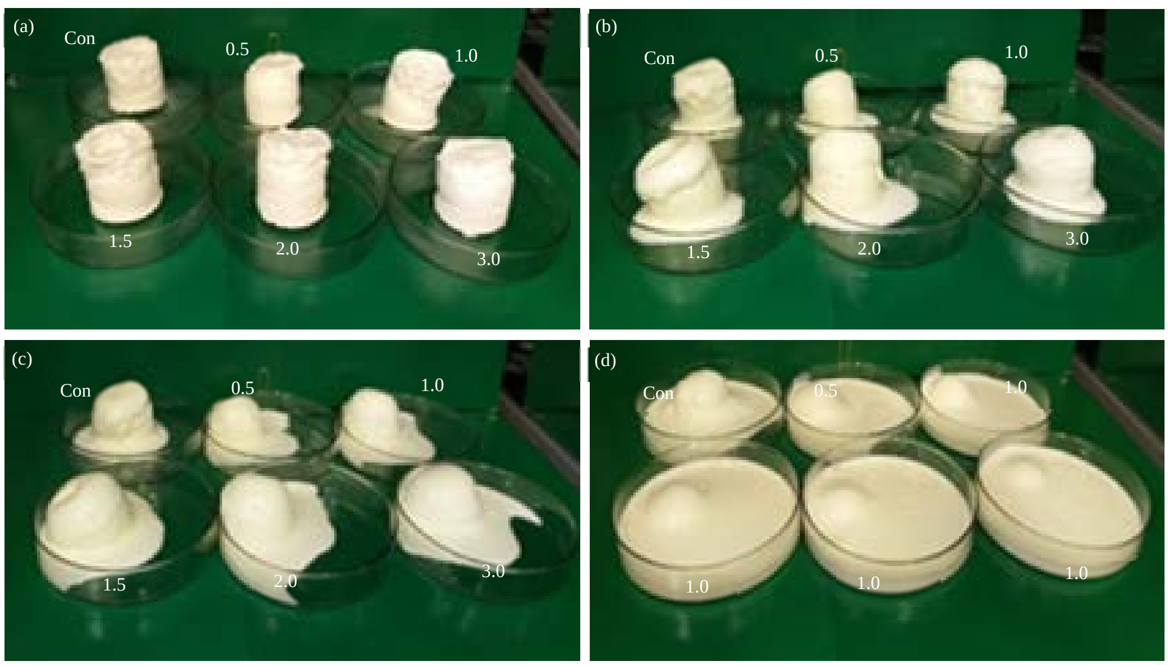

Fig 6(a-d): Dimensional stability images of ice cream samples supplemented with different concentrations of the wheat germ oil extract during holding for (a) zero time, (b) 30 min, (c) 60 min and (d) 100 min in thermostat at 20°C

Table 4: Sensory properties of ice cream samples supplemented with different concentrations of the wheat germ oil extract

Ice cream samples	Appearance	Body & texture	Taste & aroma	Total scores
0.0% WGOE	1±0.0	2.6±0.21	5.3±0.20	8.9±0.21
0.5% WGOE	1±0.0	2.5±0.14	5.3±0.24	8.8±0.22
1.0% WGOE	1±0.0	2.7±0.16	5.4±0.21	9.1±0.30
1.5% WGOE	1±0.0	2.5±0.10	5.1±0.21	8.6±0.28
2.0% WGOE	1±0.0	2.6±0.15	5.0±0.30	8.6±0.43
3.0% WGOE	1±0.0	2.4±0.13	4.5±0.08	7.9±0.16

Means (n=3 ±SD) with same letters in the same column are not significantly different ($P < 0.05$); WGOE, wheat germ oil extract

Sensory properties: The effect of added WGOE on the sensory properties of ice cream samples is shown in Table 4. The WGOE did not affect the appearance of all ice cream samples at different concentrations. The texture and flavor were similar in the control sample and ice cream samples containing WGOE, up to 1.0%. Thereafter, they were decreased; the decrease was significant only at level > 1.5% WGOE. In general, the control sample and ice cream samples containing 0.5 and

1.0% WGOE showed similarity with each other for total scores: similar in sweetness, smoothness and meting properties scores into the mouth. However, the lowest overall total scores ($P > 0.05$) were given to samples containing 3.0% WGOE and 2.0% WGOE, respectively. Reduced structure scores may be related to a decrease in overrun and thus obtained a more compressed structure.

CONCLUSION

The final structure of ice cream depends on many different processing variables, ingredients and composition that tend to have a complex function to each other. The minor lipid components of plant oils can play an important role in the dairy industry, not only to improve their nutritional values and health benefits but also to improve their physical properties and microstructure. The addition of WGOE increased the mix viscosity and the air cell size of the ice cream while reducing the ice crystal size and the melting resistance. Additionally, the WGOE can be used to produce functional ice cream rich in bioactive minor components such as tocopherols, phospholipids, phenolic compounds and phytosterols that can increase the level of vitamin E and help prevent cholesterol absorption.

SIGNIFICANCE STATEMENT

This study has determined the rational dose of minor components extract from wheat germ oil for the production of ice cream that can be a positive influence on the functional and technological properties of both soft and hardened ice cream. The results of the research are leading contributions and provide the possibility to produce dairy products with higher quality. This study will help dairy researchers and laboratory practice for using minor components for manufacturing foodstuffs of functional nutrition, obtaining objective and comparable results for ice cream properties.

REFERENCES

1. Bahramparvar, M. and M.M. Tehrani, 2011. Application and functions of stabilizers in ice cream. Food Rev. Int., 27: 389-407.
2. Goff, H.D. and R.W. Hartel, 2013. The Ice Cream Industry. 7th Edn., Springer, US, 17.
3. Erkaya, T., E. Dağdemir and M. Şengul, 2012. Influence of Cape gooseberry (*Physalis peruviana* L.) addition on the chemical and sensory characteristics and mineral concentrations of ice cream. Food Res. Int., 45: 331-335.
4. El-Shenawy, M., M. Abd El-Aziz, W. Elkholy and M.T. Fouad, 2016. Probiotic ice cream made with tiger-nut (*Cyperus esculentus*) extract. Am. J. Food Technol., 11: 204-212.
5. Gasmalla, M.A.A., 2017. Health benefits of milk and functional dairy products. MOJ Food Process Technol., 4: 108-111.
6. Chen, B., D.J. McClements and E.A. Decker, 2011. Minor components in food oils: a critical review of their roles on lipid oxidation chemistry in bulk oils and emulsions. Crit. Rev. Food Sci. Nutr., 51: 901-916.
7. Kamal Eldin, A., 2005. Minor Components of Fats and Oils. 6th Edn., John Wiley & Sons Hoboken, New Jersey, United States, pp: 319–359.
8. Salem, S.A., I.S. Ashoush and A.A. Al-Hassan, 2014. Enrichment of functional properties of ice cream with red grape pomace extract. Egypt. J. Food Sci., 42: 45-54.
9. De Camargo, A.C., M. Franchin and F. Shahidi, 2018. Tocopherols and tocotrienols: sources, analytical methods, and effects in food and biological systems. In: Reference Module in Food Science, De Camargo, A.C., M. Franchin and F. Shahidi, Elsevier, Amsterdam, Netherlands, pp: 561-570.
10. Bikheet, M., W. Abdel-Aleem and O. Khalil, 2018. Supplemented ice milk with natural bioactive components from roselle calyces and cinnamon extracts. J. Food Dairy Sci., 9: 229-235.
11. Sagdic, O., I. Ozturk, H. Cankurt and F. Tornuk, 2012. Interaction between some phenolic compounds and probiotic bacterium in functional ice cream production. Food Bioprocess Technol., 5: 2964-2971.
12. Naeem, M.A., L.K. Hassan and M.A. El-Aziz, 2019. Enhancing the pro-health and physical properties of ice cream fortified with concentrated golden berry juice. Acta Scientiarum Polonorum Technol. Aliment., 18: 97-107.
13. Gabbi, D.K., U. Bajwa and R.K. Goraya, 2017. Physicochemical, melting and sensory properties of ice cream incorporating processed ginger (*Zingiber officinale*). Int. J. Dairy Technol., 71: 190-197.
14. Guler-Akin, M.B., B. Goncu and M.S. Akin, 2016. Some properties of probiotic yoghurt ice cream supplemented with carob extract and whey powder. Adv. Microbiol., 06: 1010-1020.
15. Di Criscio, T., A. Fratianni, R. Mignogna, L. Cinquanta, R. Coppola, E. Sorrentino and G. Panfili, 2010. Production of functional probiotic, prebiotic, and synbiotic ice creams. J. Dairy Sci., 93: 4555-4564.
16. Abd El-Aziz, M., H.F. Haggag, M.H. Kaluoubi, L.K. Hassan, M.M. El-Sayed and A.F. Sayed, 2015. Physical properties of ice cream containing cress seed and flaxseed mucilages compared with commercial guar gum. Int. J. Dairy Sci., 10: 160-172.
17. Güven, M., M. Kalender and T. Taşpinar, 2018. Effect of using different kinds and ratios of vegetable oils on ice cream quality characteristics. Foods, Vol. 7. 10.3390/foods7070104

18. Miraliakbari, H. and F. Shahidi, 2008. Antioxidant activity of minor components of tree nut oils. Food Chem., 111: 421-427.
19. Frank, J.F. and H.M. Wehr, 2004. Standard Methods for the Examination of Dairy Products. 17th Edn., Am. Public Health Assoc., Washington, DC .
20. Daw, E. and R.W. Hartel, 2015. Fat destabilization and melt-down of ice creams with increased protein content. Int. Dairy J., 43: 33-41.
21. Chang, Y. and R.W. Hartel, 2002. Measurement of air cell distributions in dairy foams. Int. Dairy J., 12: 463-472.
22. Arellano, M., H. Benkhelifa, D. Flick and G. Alvarez, 2012. Online ice crystal size measurements during sorbet freezing by means of the focused beam reflectance measurement (FBRM) technology. Influence of operating conditions. J. Food Eng., 113: 351-359.
23. Alvarez, V.B., C.L. Wolters, Y. Vodovotz and T. Ji, 2005. Physical properties of ice cream containing milk protein concentrates. J. Dairy Sci., 88: 862-871.
24. Grujić, S., B. Odžaković and M. Ciganović, 2014. Sensory analysis as a tool in the new food product development. Proceedings of II International Congress Food Technology Quality and Safety, University of Novi Sad, pp:28-30.
25. SAS., 2006. Statistical Analysis System. SAS users. Cary. NC: Statistics SAS Institute.
26. Colak, N., H. Torun, J. Gruz, M. Strnad, M. Subrtova, H. Inceer and F. Ayaz, 2016. Comparison of phenolics and phenolic acid profiles in conjunction with oxygen radical absorbing capacity (ORAC) in berries of Vaccinium arctostaphylos L. and V. myrtillus L. Pol. J. Food Nutr. Sci., 66: 85-91.
27. Fernandez-Orozco, R., L. Li, C. Harflett, P.R. Shewry and J.L. Ward, 2010. Effects of environment and genotype on Phenolic acids in wheat in the HEALTHGRAIN diversity screen. J. Agric. Food Chem., 58: 9341-9352.
28. Zhu, F., Y.Z. Cai, M. Sun and H. Corke, 2008. Effect of phenolic compounds on the pasting and textural properties of wheat starch. Starch - Stärke, 60: 609-616.
29. Bajad, D.N., S.D. Kalyankar, S.D. Dehmukh, P.R. Bachanti and G.S. Bajad, 2016. Impact of physico-chemical properties of mix on the final quality of ice-cream. Asian J. Dairy Food Res., 35: 293-297.
30. Syed, Q.A., 2018. Effects of different ingredients on texture of ice cream. J. Nutr. Health Food Eng., 8: 422-435.
31. Szwajgier, D. and W. Gustaw, 2015. The effect of the addition of selected phenolic acids on the rheological properties of heated solutions of whey proteins. Acta Alimentaria, 44: 204-210.
32. Marshall, R.T., H.D. Goff and R.W. Hartel, 2003. Ice Cream. 6th Edn., Kluwer Academic/Plenum Publisher, New York, ISBN: 0-306-47700-9, pp: 78.
33. Wu, B., D.O. Freire and R.W. Hartel, 2019. The effect of overrun, fat destabilization, and ice cream mix viscosity on entire meltdown behavior. J. Food Sci., 84: 2562-2571.
34. Peng, F., S. He, H. Yi, O. Li, W. Xu, R. Wang and Y. Ma, 2018. Physical, textural, and rheological properties of whipped cream affected by milk fat globule membrane protein. Int. J. Food Prop., 21: 1190-1202.
35. Muse, M.R. and R.W. Hartel, 2004. Ice cream structural elements that affect melting rate and hardness. J. Dairy Sci., 87: 1-10.
36. Sofjan, R.P. and R.W. Hartel, 2004. Effects of overrun on structural and physical characteristics of ice cream. Int. Dairy J., 14: 255-262.
37. Warren, M.M. and R.W. Hartel, 2018. Effects of emulsifier, overrun and dasher speed on ice cream microstructure and melting properties. J. Food Sci., 83: 639-647.
38. Abd El-Rahman, A.M., S.A. Madkor, F.S. Ibrahim and A. Kilara, 1997. Physical characteristics of frozen desserts made with cream, anhydrous milk fat, or milk fat fractions. J. Dairy Sci., 80: 1926-1935.
39. Park, S.H., Y.J. Jo, J.Y. Chun, G.P. Hong, M. Davaatseren and M.J. Choi, 2015. Effect of frozen storage temperature on the quality of premium ice cream. Korean J. Food Sci. Anim. Resour., 35: 793-799.
40. Amador, J., R. Hartel and S. Rankin, 2017. The effects of fat structures and ice cream mix viscosity on physical and sensory properties of ice cream. J. Food Sci., 82: 1851-1860.
41. Schmidt, K.A. and D.E. Smith, 1992. Rheological properties of gum and milk protein interactions. J. Dairy Sci., 75: 36-42.
42. Abd El-Aziz, M., G.A. Mahran, A.A. Asker, A.F. Sayed and S.S. El-Hadad, 2013. Blending of butter oil with refined palm oil: Impact on physicochemical properties and oxidative stability. Inter. J. Dairy Sci., 8: 36-47.
43. Talbot, G., K. Smith and K. Bhaggan, 2002. Influence of minor components on fat crystallization. Lipid Technol., 24: 83-85.