Annals of Phytomedicine 11(1): 588-594, 2022

DOI: http://dx.doi.org/10.54085/ap.2022.11.1.68

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885

Original Article : Open Access

Development of functional ice cream using niger (*Guizotia abyssinica* (L.f.) Cass.) seed oil microcapsules

Vikas Patel, Dinesh Chandra Rai◆, Uday Pratap Singh and Aman Rathaur
Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India

Article Info

Article history
Received 25 April 2022
Revised 12 June 2022
Accepted 13 June 2022
Published Online 30 June 2022

Keywords
Antioxidant activity
Functional ice cream
Niger seed oil
Sensory quality
Total phenolic content

Abstract

To meet rising customer demand, the food sector is constantly working to develop healthier functional foods. The medicinal and therapeutic properties of niger seeds are highly valued. The current study examined that the incorporation of niger seed oil microcapsules into ice cream. An ice cream mix with 14% sucrose, 10% milk fat, 0.5% emulsifier and 0.5% stabilizer was prepared. Spray-drying technique was used for the microencapsulation of niger seed oil by utilizing maltodextrin and sodium casienate, as wall materials. Both the non-encapsulated and encapsulated niger seed oil were used for incorporation into ice cream and optimized based on antioxidant activity, total phenolic contents, sensory, viscosity, overrun and hardness. The sample of ice cream with 2% niger seed oil had highest values of DPPH inhibition (88.73%) and TPC (24.23 mg GA eq./g), while the sample of ice cream possessing 1% encapsulated powder was found best in terms of sensory profile viscosity, overrun and hardness among other variants. The total polyphenolic contents increased proportionally with increasing levels of encapsulated as well as non-encapsulated niger seed oil. Therefore, niger seed oil could be used as a naturally occurring ingredient to develop a novel ice cream with high antioxidant activity.

1. Introduction

Milk production in India is the highest in the world, with 50% of it being used by the unorganized sectors to produce many delicacies (Rai *et al.*, 2020). The most popular dessert in the world is ice cream, which has a frozen combination of milk, dairy products, and sweets. In addition to being popular with people of all ages, ice cream is majorly consumed product in the varied group of dairy desserts (Legassa, 2020). New goods have been created as a result of growing understanding and study on the relationship in between health and food, as well as the technological demand for constant innovations. Some of these products hold functional potential to promote the health of mankind (Granato *et al.*, 2018). The chemical composition of ice cream influences a number of crucial structural and sensory aspects that affect the end product's quality (Syed *et al.*, 2018). In traditional ice creams, sugar and fat are considered to be high concentrations, which are the main components in terms of caloric content. As health and nutrition concerns have grown, low-calorie and reduced-fat products have been growing in popularity, since their consumption reduces the risk of diseases like heart disease and cancer (Akalin *et al.*, 2018). It is estimated that at least 25% of all modern medicines are derived directly or indirectly from plants, thanks to the application of modern technologies to traditional knowledge (Bouatrous, 2019). In order to meet these needs, the food industry has been looking for alternative ingredients that do not change the aroma, texture, as well as flavor in the traditional foods.

Niger (*Guizotia abyssinica* (L.f.) Cass.) seed is a member of the Compositae family, similar to safflower and sunflower seeds. India along with Ethiopia are the two countries majorly producing niger seed in the world (Muhammed *et al.,* 2021). The oil cake left after extraction of niger oil from the niger seeds is a rich source of oil, protein and fiber, free form harmful substances is suitable to be fed to all the types of animals, capable to digest fibrous feeds. The average content of oil in niger seed has been delineated in the range of 40 to 44%. Niger seed oil also contains immense amounts of essential fatty acids; namely, omega-6 polyunsaturated fatty acid in 63-75% amount (Bhatnagar and Krishna, 2013). Natural fats and oils contain lipophilic components in addition to triacylglycerols, with polar lipids such as glycolipids and phospholipids being among the most fascinating.

Increased demand for healthier and more functional foods led to the manufacture of ice cream with functional properties such as antioxidants. It is a superior carrier for essential oils' bioactive components (Pandhi *et al.,* 2021). The incorporation of beneficial additives to the ice cream increases its value. The current study aims to intensify the nutritional characteristics and the sensory attributes of ice cream by incorporating spray-dried niger seed oil microcapsulules.

2. Materials and Methods

Milk was procured from the Dairy farm, Institute of Agricultural Sciences, BHU, Varanasi, U.P., India. Milk was standardized to

Corresponding author: Dr. Dinesh Chandra Rai
Professor and Head Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India
E-mail: dcrai@bhu.ac.in
Tel.: +91-9415256645

6.0% fat and 8.5% SNF and table cream with fat content of 25% as well as skimmed milk powder were used to develop ice cream. Niger seed oil (NSO) was procured from Oil Cure Health (Bangalore, India) and then encapsulated using a two-to-one ratio (core to wall material). All the chemicals and reagents used, were of analytical grade obtained from Hi Media Laboratories Pvt. Ltd., Mumbai, India.

2.1 Production of niger seed oil microcapsules

The niger seed oil microcapsuless (NSOM) were prepared utilizing maltodextrin (MD): sodium casienate (SC) (2:1), as the wall material. Production of NSOM was conducted using a mini spray dryer from JISL. For the development of the functional ice cream, spray-dried niger seed oil powder was utilized.

2.2 Production of the functional ice cream

The functional ice cream was prepared in ice cream plant of the Department of Dairy Science and Food Technology, Institute of Agricultural Science, BHU, Varanasi. The methods for the formulation of ice cream and its sample preparation were acquired according to Sacchi *et al.* (2019) after slight modifications. Figure 1 illustrates the process of making ice cream. The Pearson square equation was employed to standardize amount of fat and solid in the ice cream mix. In ice cream formulation, 1000 ml of pasteurized milk, 14% sugar, 0.5% emulsifier and 0.5% stabilizer were used. The percentage of total solids, protein and milk fat in the control sample were 36%, 3.5% and 10%, respectively. This study used five different treatment combinations in the form of ice creams constructed on the absence or presence of niger seed oil powder: T1 (control ice cream); T2 (ice cream consisting 1% (w/v) niger seed oil microcapsuls (NSOM); T3 (ice cream with 2% (w/v) niger seed oil microcapsuls (NSOM), T4 (ice cream consisting 1% (w/w) niger seed oil (NSO); T5 (ice cream with 2% (w/w) niger seed oil (NSO). For the making of functional ice cream, the milk was first heated to temperature of 85°C, later followed by addition of all the ingredients to milk with constant stirring for 1 min. Afterwards, the resulted mixture was ultimately cooled to 4°C. The resultant mixture was stirred slowly for time interval of about 8 h during the ageing phase. After the ice cream had been cooled down and frozen, the hardened ice cream was stored in deep freezer which was maintained at – 18°C for time period of 24 h, before being analyzed as per Paul *et al.* (2020).

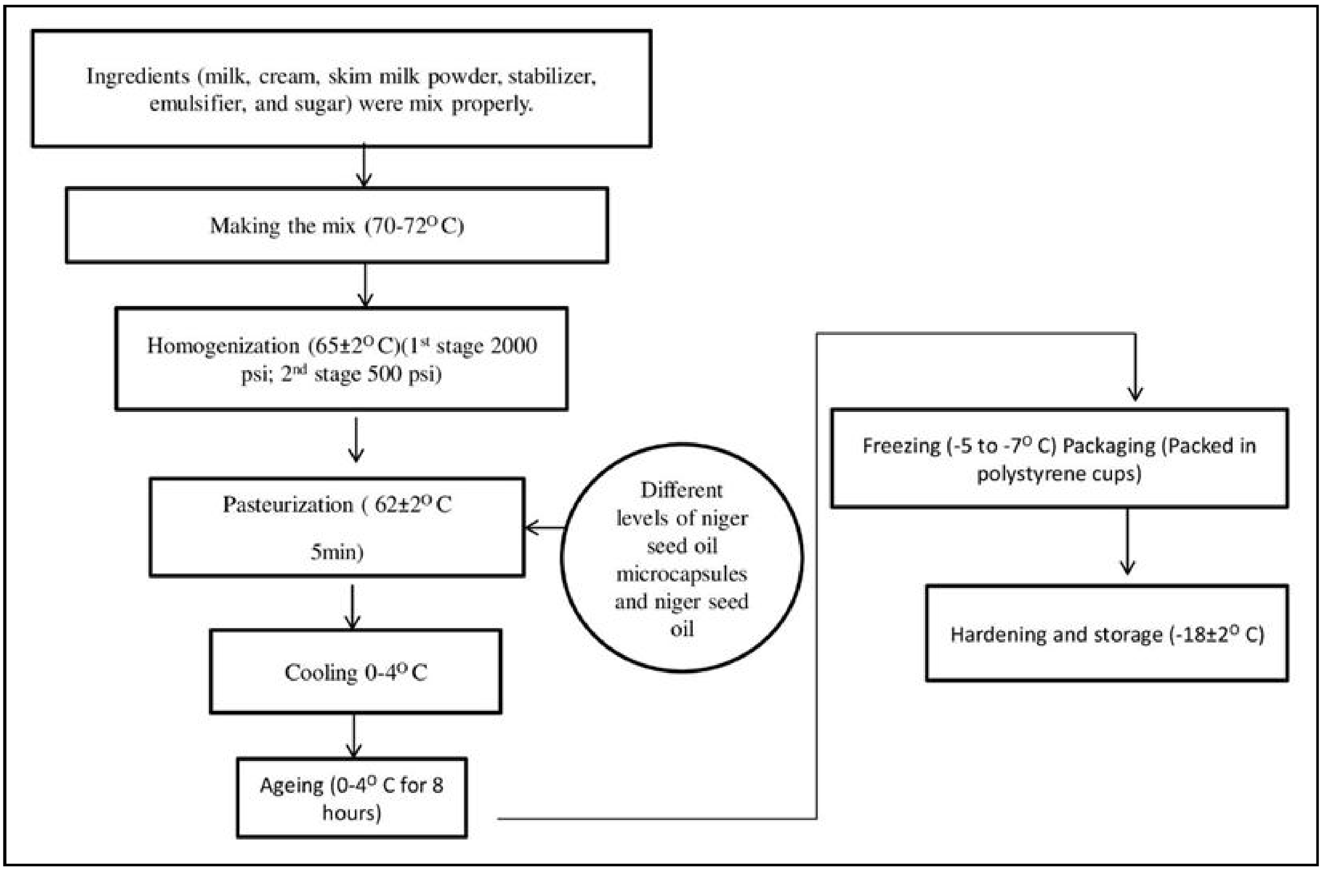

Figure 1: Process flow chart of niger seed oil microcapsules.

2.3 Characterization of ice cream

2.3.1 Overrun

The overrun was examined by method according to Samakradhamrongthai *et al.* (2021) by using equation mentioned below:

$$\text{Overrun} = \frac{\text{Wt.1} - \text{Wt.2}}{\text{Wt.2}} \times 100$$

where,

Wt_1 = Weight of ice cream mix

Wt_2 = Weight of ice cream

Table 1: Effect of niger seed oil microcapsules on overrun, viscosity and hardness of the ice cream

Treatments	Viscosity	Overrun	Hardness
T1	45.33 ± 0.68	69.06 ± 0.49	52.63 ± 0.22
T2	85.48 ± 0.72	76.55 ± 0.13	41.70 ± 0.24
T3	84.16 ± 0.96	77.01 ± 0.27	40.32 ± 0.66
T4	82.31 ± 0.89	74.06 ± 0.17	43.30 ± 0.75
T5	80.23 ± 1.08	75.00 ± 0.10	44.50 ± 0.71

Table 2: DPPH inhibition % and TPC assessments of different ice cream samples incorporated with encapsulated and non-encapsulated niger seed oil

Treatments	Antioxidant (%)	Phenolic content(μg GAE/ml)
T1	65.12 ± 0.12	0
T2	86.27 ± 0.23	21.85 ± 0.05
T3	87.40 ± 0.15	23.11 ± 0.10
T4	87.25 ± 0.20	22.54 ± 0.08
T5	88.73 ± 0.27	24.23 ± 0.20

Table 3: Sensorial evaluations of different ice cream samples encapsulated and non-encapsulated niger seed oil

Treatments	Color and appearance	Body and texture	Flavor	Mouth feel	Overall
T1	7.9 ± 1.10	7.9 ± 1.29	8.10 ± 1.45	7.50 ± 1.65	7.70 ± 1.34
T2	7.9 ± 1.37	7.7 ± 1.34	8.10 ± 1.20	7.50 ± 1.43	7.70 ± 1.57
T3	7.8 ± 1.55	7.6 ± 1.51	7.80 ± 1.32	7.30 ± 1.49	7.30 ± 1.49
T4	7.7 ± 1.42	7.9 ± 1.20	5.80 ± 1.40	5.70 ± 1.57	5.80 ± 1.55
T5	7.3 ± 1.25	7.8 ± 1.55	5.10 ± 1.52	5.00 ± 1.56	5.00 ± 1.33

2.3.2 Mix viscosity

At a shear rate of 100 rpm, Brookfield viscometers with LV spindles 63 (BRK Instruments India LLP, Thane, India) were used for measuring the apparent viscosity of formulated ice cream mix according to Muse and Hartel (2004).

2.3.3 Hardness measurement

A TA.XT plus texture analyzer (Stable Micro System, Godalming, UK) with a 2 mm (diameter) cylinder probe was used to measure the hardness at room temperature (25 ± 2°C) of the ice cream. For this evaluation, 1 mm/s was used for penetration speed and 25 mm was penetrated with a trigger force of 5 g (Yan *et al*., 2021). In 100 ml plastic cups, the samples were taken and the measurement of hardness property of ice cream was in terms of grams.

2.4 Quantification of antioxidant and phenolic properties of ice cream

For calculation of DPPH scavenging activity method determined by Sutaphanit and Chitprasert (2014) was used. 200 μl of sample was taken for this study, and at wavelength of 517 nm. The absorbance was recorded, using a UV-VIS spectrophotometer (Shimadzu, Japan). The formula to calculate the percentage DPPH inhibition of the formulated samples:

$$\text{Percentage DPPH inhibition} = (A_1 - A_0)/A_1 \times 100$$

where,

A_1 = Absorbance of the control

A_0 = Observed final absorbance of extracted sample at the wavelength of 517 nm.

For blank 95% methanol was used.

Krawitzky *et al*. (2014) procedure was conducted to measure total phenolic content (TPC) of the samples. For this study, 100 μl of the sample was drawn, later followed by measurement of absorbance by UV-VIS spectrophotometer (Shimadzu, Japan) at wavelength of 760 nm. The total phenolic contents were calculated and represented in gallic acid equivalent (μg GAE/ml) terms.

2.5 Sensory evaluation

The evaluation of prepared ice creams on sensory basis was carried in the Department of Dairy Science and Food Technology, BHU, Varanasi, following with the method represented by Dertli *et al*. (2016) with minor modifications. Ten panelists (five males and females) were picked out in random manner among the members of faculty, research scholars and postgraduate students at the Department of Dairy Science and Food Technology, BHU, Varanasi.

The panelists were familiarized with the procedure of sensory evaluation, before conducting the test. For the assessment of samples' sensorial attributes and quality, each panelist member evaluated developed ice cream employing 9-point hedonic scale. The evaluations were conducted at room temperature (25 ± 2°C). The liking degree of respective samples was examined by a scale with range of 1 to 9 points where 1 point being the dislike extremely and the 9: like extremely.

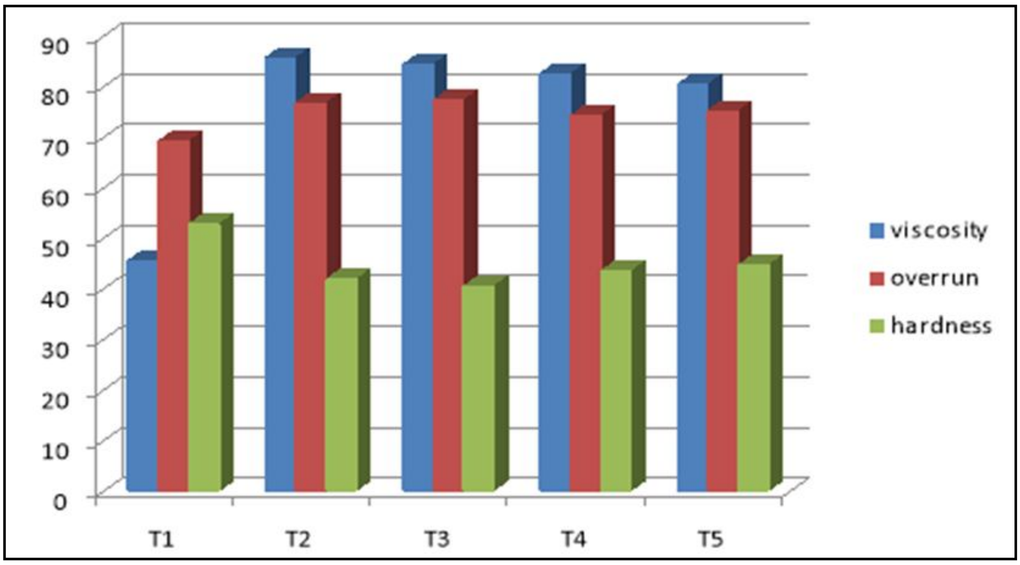

Figure 2: Effect of niger seed oil microcapsules on viscosity, overrun, and hardness of ice cream.

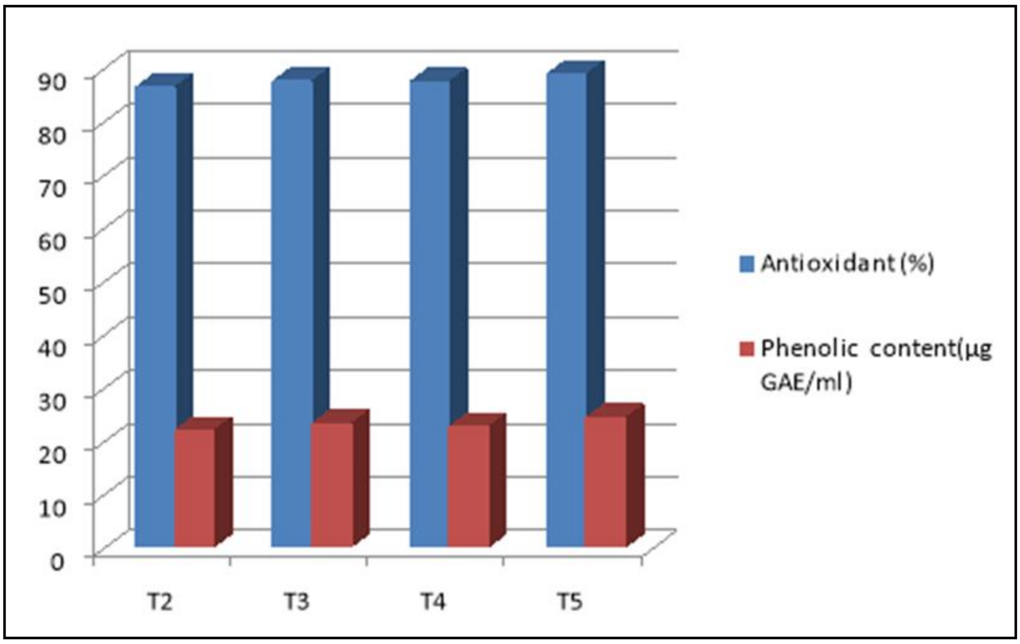

Figure 3: Effect of niger seed oil microcapsules on antioxidant and phinolic content of ice cream.

2.6 Statistical analysis

For quantification of sensory and physicochemical features of ice cream, the entire experiment was carried out in triplicate. With SPSS version 25, calculated the significance of the differences between samples using one-way analysis of variance. The parameter effects of the corresponding factor were considered statistically significant if, the difference was greater than ($p<0.05$).

3. Results

3.1 Characterization of ice cream

3.1.1 Effect of niger seed oil microcapsules on overrun, viscosity and hardness of the ice cream.

The characterization properties of developed ice cream is shown in Table 1. The resulted overrun of ice cream ranged between 77%.

The overrun resulted from NSOM ice cream (76 ± 0.09%) was spotted to be higher than the control (69 ± 0.07%) and NSO ice cream (75 ± 0.05%) (Figure 2). The viscosity range of ice cream was observed from 46-86%. The results showed that NSOM ice cream a higher viscosity when compared to control. There were minor variations observed in viscosity of NSOM ice cream in contrast to NSO ice cream (84 ± 0.18 cP). The parameter of hardness of ice cream samples was in between the range of 41.05-53.14 g. The hardness of NSOM ice cream (41.05 ± 0.06 g) and NSO ice cream (44.5 ± 0.19 g) exhibited minor variation. For the control ice cream, the hardness (53.14 ± 0.18 g) was higher when compared to NSOM ice cream.

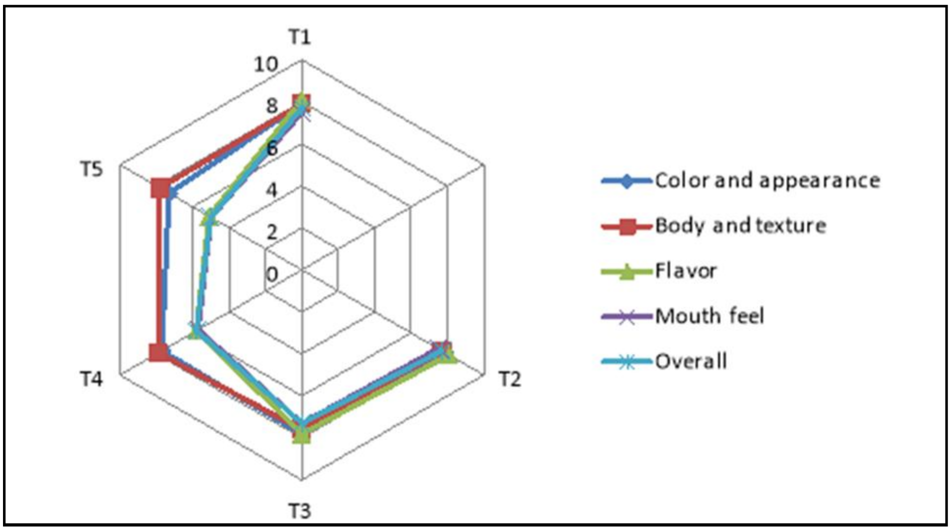

Figure 4: Effect of niger seed oil microcapsules on sensory evaluation of ice cream

3.1.2 Quantification of phenolic and antioxidant properties of ice cream

Total phenolic content (TPC) and antioxidant property of NSOM and NSO ice cream is shown in Table 2. The TPC of NSOM ice cream (T2 21.85 ± 0.05 and T3 23.11 ± 0.10 µg GAE/ml) and NSO ice cream (T4 22.54 ± 0.08 and T5 24.23 ± 0.20 µg GAE/ml) (Figure 3). The percentage DPPH inhibition of NSOM ice cream was (T2 86.27 ± 0.23 and T3 87.4 ± 0.15%), and NSO ice cream (T4 87.25 ± 0.20 and T5 88.73 ± 0.27%).

3.2 Sensory evaluation

The sensory scores acquired for following sensory parameters: body and texture, color and appearance, mouth feel, flavor and overall acceptability of all five ice cream samples are shown in Table 3. Slight difference of the sensorial properties was depicted in between the control and NSOM ice cream (Figure 4). The color and appearance attributes of NSOM ice cream (T2 7.9 ± 1.10 and T3 7.8 ± 1.37) and NSO ice cream (T4 7.7 ± 1.42 and T5 7.3 ± 1.25). Due to the added viscosity caused by adding microcapsules to the ice cream, treatments T1 and T3 had a greater body and texture than treatment T2. The flavor score of the control and NSOM, ice cream T2 were 8.1 ± 1.81, 8.1 ± 1.56, respectively flavor score NSO ice cream T5 was lower 5.10 ± 1.52 than the other treatment. Mouth feel attribute of the control and NSOM ice cream T2 were 8.10 ± 1.45. In contrast, NSO ice cream T4 and T5 gives slightly bitter after taste, possessing average rating of 5.70 ± 1.57, 5.00 ± 1.56, respectively. The overall acceptability score of treatments T1 and T2 was 7.70 ± 1.34 and 7.70 ±1.34, which was higher than the other treatment.

4. Discussion

The amount of air in ice cream that generates bubbles that must be generated and stabilized is known as overrun. The texture and sensory qualities of ice cream are determined by the presence of air, which is illustrated by overrun of ice cream (Kurt and Atalar, 2018). Incorporation of niger seed oil and the encapsulated niger seed oil increased the respective overrun of NSO and NSOM ice cream. Overrun in in NSOM ice cream treatment T2, T3 was slightly higher than treatment NSO ice cream T4, T5. This finding was in compliance with Velotto *et al.* (2021). The increment of overrun revealed to improved stability in the ice cream mix. On the other hand, the overrun of all the ice cream samples were lower than 129-144% overrun as noted by Borrin *et al.* (2018) after incorporation of curcumin-nanoemulsion. The higher overrun of NSO ice cream might be attributable to large amount of fat, which would ultimately increase the value of apparent viscosity of ice cream mix and, therefore, incorporate additional air as it freezes (Makouie *et al.*, 2021). The recorded value of apparent viscosity for NSOM ice cream T2 and T3 were slightly higher than that of NSO ice creamT4 and T5 showed in Table 1. This is because of the use of carbohydrate as wall material (MD and SC) for the encapsulation of NSO. Carbohydrates are responsible for increasing the viscosity of food (Lima *et al.*, 2016). Viscosity correlates with the efficiency of breaking down air cells. In consequence of the addition of niger seed oil powder, the viscosity increased. The NSOM ice cream exhibited higher viscosity than that of control. Hardness property of ice cream is influenced by various factors of ice cream mix such as viscosity, amount of solid and air (Yan *et al.*, 2021). Ice cream's overrun and the hardness are indirectly proportional, because as the overrun increases, the hardness decreases. Kulkarni *et al.* (2017) studied the effect of the pumpkin powder incorporation in the ice cream. They concluded that after addition of pumpkin powder the viscosity increases, which in turn resulted in reduced ice cream hardness. In case of DPPH scavenging activity, NSO ice cream was with accordance to Mishra *et al.* (2020). The ice cream with NSO had higher antioxidant and phenolic contents as compared to the ice cream with encapsulated NSO may be as consequence to the higher temperature of spray dryer which is used for making a powder of encapsulated NSO, generally, more than 60°C temperature reduces the activity of bioactive compounds present in NSO. Findings of this study were compared to those obtained from a previous study that found that increasing the amount of Aronia juice enhanced overall polyphenol and flavonoid content when compared to a control (Nguyen and Hwang, 2016). TPC of the ice cream increases with NSOM (T2 and T3) as compared to NSO (T4 and T5) in the formulations. The reduced phenolics value of NSO ice cream can be attributed to the loss of volatiles while the manufacturing process of the functional ice cream. Research findings of the TPC of NSOM ice cream are in accordance with Deme *et al.* (2021). The increased phenolic content within food assists in the prevention of illnesses induced by reactive oxidative stress (Durmaz *et al.*, 2020).

There was a slight difference between NSOM and NSO ice cream with regards to color and appearance. NSO ice cream delivered creamy-yellowish color. Therefore, the incorporation of NSOM had no influence on visual presentation of the ice cream. The color score findings were agreement with study conducted by Mishra *et al*. (2020). They said that color attribute of yoghurt embodied with the encapsulated seed extract was noted to be higher when compared to that of seed extract incorporated yoghurt. NSO ice cream had a similar flavor profile to Ramadan *et al*. (2012) oil-enriched ice cream, which reported a flavor score of 6.56 ± 0.88. The texture and body attribute of the NSO ice cream (T4 and T4) betokened magnified acceptance than NSOM ice cream (T2 and T3) owing to the viscosity increase with the microcapsules addition in ice creams. Agrawal *et al*. (2015) noted very minor difference in texture and body of ice cream, when with mixed with ginger juice. Basil oil ice cream gives bitter after taste. The findings of overall acceptance score was in compliance with the result obtained by Zanjani *et al*. (2018), designated that there was no off-flavor development after the addition of encapsulated probiotic strain. Hence, the above results indicated that the encapsulation strategy can minimize the unwanted feels (flavor, color, and mouth feel) of the NSO in the food products.

5. Conclusion

In this study, functional ice cream consisting NSO microcapsules was evaluated for functional and sensorial properties. These findings obtained are crucial for functional dairy sector since NSOM can be further incorporated into various dairy-based products, thanks to their high stability of sensory attributes and bioactive components. In addition, sensory attributes of ice cream demonstrated that the incorporation of the NSOM did not considerably affect body and texture, color and appearance, taste, mouth feel and overall acceptability. Additionally, a conclusion can be derived that the bioactive compounds from various essential oils can be used in food product like a natural bioactive ingredient for the improvement of their nutritional as well as sensory properties.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

References

Agrawal, A. K.; Karkhele, P. D.; Karthikeyan, S.; Shrivastava, A. and Sinha, G. (2016). Effect of variation of ginger juice on some physical and sensory properties of ice cream. Indian J. Dairy Sci., **69**(1):17-23.

Akalýn, A. S.; Kesenkas, H.; Dinkci, N.; Unal, G.; Ozer, E. and Kinik, O. (2018). Enrichment of probiotic ice cream with different dietary fibers: Structural characteristics and culture viability. J. Dairy Sci., **101**(1): 37-46.

Bhatnagar, A. S. and Krishna, A. G. G. (2013). Effect of extraction solvent on oil and bioactives composition of commercial Indian niger (*Guizotia abyssinica* (Lf) Cass.) seed. J. Am. Oil Chem.' Soc., **90**(8):1203-1212.

Borrin, T. R.; Georges, E. L.; Brito Oliveira, T. C.; Moraes, I. C. and Pinho, S. C. (2018). Technological and sensory evaluation of pineapple ice creams incorporating curcumin loaded nanoemulsions obtained by the emulsion inversion point method. Int. J. Dairy Technol., **71**(2):491-500.

Bouatrous, Y. (2019). Antibacterial activity of an essential oil and various extracts of the medicinal plant *Thymus hirtus* sp. *algeriensis* Boiss. and Reut. Ann. Phytomed., **8**(2):108-114.

Deme, T.; Haki, G. D.; Retta, N.; Woldegiorgis, A. and Geleta, M. (2021). Fatty acid profile, total phenolic content, and antioxidant activity of niger seed (*Guizotia abyssinica*) and linseed (*Linum usitatissimum*). Front. Nutr., **8**:1-13. https://doi.org/10.3389/fnut.**21**:674882.

Dertli, E.; Toker, O. S.; Durak, M. Z.; Yilmaz, M. T.; Tatlýsu, N. B.; Sagdic, O. and Cankurt, H. (2016). Development of a fermented ice-cream as influenced by in situ exopolysaccharide production: Rheological, molecular, microstructural and sensory characterization. Carbohydr, Polym., **136**:427-440. https://doi.org/10.1016/j.carbpol.2015.08.047.

Durmaz, Y.; Kilicli, M.; Toker, O. S.; Konar, N.; Palabiyik, I. and Tamturk, F. (2020). Using spray-dried microalgae in ice cream formulation as a natural colorant: Effect on physicochemical and functional properties. Algal Res., **47**:101-811. https://doi.org/10.1016/j.algal.2020.101811.

Granato, D.; Santos, J. S.; Salem, R. D.; Mortazavian, A. M.; Rocha, R. S. and Cruz, A. G. (2018). Effects of herbal extracts on quality traits of yogurts, cheeses, fermented milks, and ice creams: A technological perspective. Curr. Opin. Food Sci., **19**:1-7. https://doi.org/10.1016/j.cofs.2017.11.013.

Krawitzky, M.; Arias, E.; Peiro, J. M.; Negueruela, A. I.; Val, J. and Oria, R. (2014). Determination of color, antioxidant activity, and phenolic profile of different fruit tissue of Spanish 'Verde Doncella'apple cultivar. Int. J. Food Prop., **17**(10):2298-2311.

Kulkarni, A. S.; Joshi, D. C.; Tagalpallewar, G. and Gawai, K. M. (2017). Development of technology for the manufacture of pumpkin ice cream. Indian J. Dairy Sci., **70**(6):701-706.

Kurt, A. and Atalar, I. (2018). Effects of quince seed on the rheological, structural and sensory characteristics of ice cream. Food Hydrocoll., **82**:186-195. https://doi.org/10.1016/j.foodhyd. 2018.04.011.

Legassa, O. (2020). Ice cream nutrition and its health impacts. Int. J. Food Nutr. Sci., **7**(1):19-27.

Lima, J. G. D.; Brito-Oliveira, T. C. and Pinho, S. C. D. (2016). Characterization and evaluation of sensory acceptability of ice creams incorporated with beta-carotene encapsulated in solid lipid microparticles. Food Sci. Technol., **36**(4):664-671.

Makouie, S.; Alizadeh, M.; Khosrowshahi, A. and Maleki, O. (2021). Physicochemical, textural, and sensory characteristics of ice cream incorporated with *Nigella sativa* seed oil microcapsules. J. Food Process. Preserv., **45**(10):e15804.

Mishra, S.; A., Rai, D. C. and Pandhi, S. (2020). Process optimization for yogurt preparation incorporated with encapsulated *Caesalpinia bonducella* Flem. seed extract. Ann. Phytomed., **9**(1):224-228.

Muhammed, Z. S. and Mahmood, B. J. (2021). Influnce of cultivars, plant geometry, humic acid and their interactions on growth and yield of niger (*Guizotia abyssinicia* Cass.) Crop. ZANCO Journal of Pure and Applied Sciences, **33**(6):72-89.

Muse, M. R. and Hartel, R. W. (2004). Ice cream structural elements that affect melting rate and hardness. J. Dairy Sci., **87**(1):1-10.

Nguyen, L. and Hwang, E. S. (2016). Quality characteristics and antioxidant activity of yogurt supplemented with aronia (*Aronia melanocarpa*) Juice. Prev. Nutr. Food Sci., **21**(4):330-337.

Pandhi, S.; Arvind and Gupta, A. (2021). Functional dairy foods: The way forward after COVID-19. Ann. Phytomed, **10**(1):S251-S256.

Paul, V.; Arvind; Rai, D. C.; Pandhi, S. and Seth, A. (2020). Development of functional ice cream using basil oil microcapsules. Indian J. Dairy Sci., **73**(6):542-548.

Rai, H. R.; Rai, D. C.; Arvind and Saloni (2020). Process optimization of low calorie and fiber enriched 'Sandesh' using response surface methodology (RSM). Ann. Phytomed., **9**(1):229-236.

Ramadan, M. F. (2012). Functional properties, nutritional value, and industrial applications of niger oilseeds (*Guizotia abyssinica* Cass.). Crit. Rev. Food Sci. Nutr., **52**(1):1-8.

Sacchi, R.; Caporaso, N.; Squadrilli, G. A.; Paduano, A.; Ambrosino, M. L.; Cavella, S. and Genovese, A. (2019). Sensory profile, biophenolic and volatile compounds of an artisanal ice cream ('gelato') functionalised using extra virgin olive oil. Int. J. Gastron. Food Sci., **18**:100-173. https://doi.org/10.1016/j.ijgfs.2019.100173.

Samakradhamrongthai, R. S.; Jannu, T.; Supawan, T.; Khawsud, A.; Aumpa, P. and Renaldi, G. (2021). Inulin application on the optimization of reduced-fat ice cream using response surface methodology. Food Hydrocoll., **119**:106-873. https://doi.org/10.1016/j.foodhyd.2021.106873.

Sutaphanit, P. and Chitprasert, P. (2014). Optimisation of microen capsulation of holy basil essential oil in gelatin by response surface methodology. Food Chem., **150**:313-320. https://doi.org/10.1016/j.foodchem.2013.10.159.

Syed, Q. A.; Anwar, S.; Shukat, R. and Zahoor, T. (2018). Effects of different ingredients on texture of ice cream. J. Nutri. Health Food Eng., **8**(6):422-435.

Velotto, S.; Parafati, L.; Ariano, A.; Palmeri, R.; Pesce, F.; Planeta, D.; Alfeo, V. and Todaro, A. (2021). Use of stevia and chia seeds for the formulation of traditional and vegan artisanal ice cream. Int. J. Gastron. Food Sci., **26**:100-441.

Yan, L.; Yu, D.; Liu, R.; Jia, Y.; Zhang, M.; Wu, T. and Sui, W. (2021). Microstructure and meltdown properties of low-fat ice cream: Effects of microparticulated soy protein hydrolysate/xanthan gum (MSPH/XG) ratio and freezing time. J. Food Eng., **291**:110-291. https://doi.org/10.1016/j.jfoodeng.2020.110291.

Zanjani, M. A. K.; Ehsani, M. R.; Ghiassi Tarzi, B. and Sharifan, A. (2018). Promoting lactobacillus casei and bifidobacterium adolescentis survival by microencapsulation with different starches and chitosan and poly L lysine coatings in ice cream. J. Food Process. Preserv., **42**(1):e13318.

Citation **Vikas Patel, Dinesh Chandra Rai, Uday Pratap Singh and Aman Rathaur (2022). Development of functional ice cream using niger (*Guizotia abyssinica* (L.f.) Cass.) seed oil microcapsules. Ann. Phytomed., 11(1):588-594. http://dx.doi.org/10.54085/ap.2022.11.1.68.**