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Development of functional shrikhand incorporated with flaxseed (*Linum usitatissimum* L.) oil microcapsules

Uday Pratap Singh, Dinesh Chandra Rai◆, Aman Rathaur and Vikas Patel

Department of Dairy Science and Food Technology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi-221 005, Uttar Pradesh, India

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Abstract

Shrikhand is a traditional Indian dessert made from fermented milk. Nutritional and medicinal awareness is increasing in the new millennium, which is enhancing customer requirements for fermented foods. In this study, flaxseed oil microcapsules were incorporated into *shrikhand*. Spray dryer was used to microencapsulate the flaxseed oil under ideal temperature and rate conditions (160°C for air inlet, 80°C for outlet), solid content (30%) in emulsion, and feed rate (20 ml/h). A 3:1 ratio of maltodextrin cross linked with sodium casienate was used as the wall material. Optimized *shrikhand* was investigated for antioxidant activity, phenolic content, sensory analysis, and texture analysis. The sample of *shrikhand* with 2% flaxseed oil (FSO) had highest values of DPPH inhibition (88.82%) and 2% flaxseed oil microcapsule (FSOM) had highest value of TPC (23.30 mg/g GA). Texture properties of *shrikhand* like springiness and firmness were also changed after adding different levels of FSOM and FSO. The level of acceptability of *shrikhand* is highest in FSOM among all treatments. Therefore, flaxseed oil could be used as a naturally occurring ingredient to develop a novel shrikhand with high antioxidant activity.

1. Introduction

India is the highest milk producer in the world and 50% of total produce is used by unorganised sector for manufacturing of many delicacies (Rai *et al*., 2020). Milk and milk products are already in high demand due to their well-being encourage properties and a well-established industry. The dairy sector is currently showing a lot of importance in producing useful dairy foods using bioactive ingredients. This method can be used to communicate the health-promoting characteristics of bioactive herbs and plants, for a specified population group (Bais, 2018).

Shrikhand is derived from the Sanskrit word "Shrikharini," which refers to a curd mixture with sugar, flavouring ingredient, fruits, and nuts (Mane *et al*., 2017). It is one of the most popular fermented milk products in Indian cuisine. In India, around 9% of all milk produced is converted into fermented dairy products with an annual growth rate of over 20% (Hussain *et al*., 2014). Fermented dairy products contribute to the synthesis of vitamin B complex in humans as well as the prevention of stomachic disorders because several lactic bacteria produce natural antibiotics (Markowiak and Slizewska, 2017). Increasing health and nutrition concerns in recent years have led to the production of at least 25% of all modern medicines directly or indirectly from plants thanks to the application of technology to traditional knowledge (Bouatrous, 2019). To meet these demands, the food industry has been on the lookout for alternative ingredients that do not alter the scent, texture, or flavour of traditional foods.

Flaxseed (*Linum usitatissimum* L.) is a source of omega-3 fatty acids (n-3, FAs) containing about 52-58% of total FAs and lignans. Moreover, flaxseed oil (FSO) contains 58% α-linolenic acid (ALA), which is a vital antioxidant source that improves animal health not only reproductively but also through improving inflammation and brain development (Ngcobo *et al*., 2021). Flaxseed oil is further comprised of stearic, oleic, linoleic and palmitic acids, which contain a high content of vitamins including vitamin E (Moallen, 2018). There are many phytoactive compounds in this oil with medicinal properties, but their direct incorporation into the food product may alter its flavor, taste, and texture. Hence, to maintain the activity of these actives, encapsulation approaches are used for entrapment (Mahdavi *et al*., 2014). The microencapsulation of FSO increases its solubility, allowing for simple FSO release. More research on supplementation of food ingredients with FSO microcapsules is needed, as this will have a favorable impact on the consumer's overall health (Rai *et al*., 2020). It is a good carrier for essential oils' bioactive components (Pandhi *et al*., 2021). Accordingly, the present study was focused on the process optimization to develop the *shrikhand* incorporated with encapsulated FSO to intensify the nutritional characteristics and the sensory attributes of *shrikhand*.

2. Materials and Methods

Full cream milk (6% fat and 9% SNF) and sugar was purchased from local market of Varanasi. Starter culture was collected from NCDC, NDRI, Karnal. Flaxseed oil was procured from Ceyon Healthcare India. The wall materials, *e.g*., maltodextrin (MD) and sodium caseinate (SC) were procured from Himedia, India.

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.: +91-8052574300

2.1 Preparation of flaxseed oil microcapsules by spray drying method

The flaxseed oil microcapsules (FSOM) were made with a wall material of MD: SC (3:1). The FSOM was produced by using a mini spray dryer from JISL. In order to develop a functional *shrikhand*, spray-dried encapsulated flaxseed oil microcapsule was applied.

2.2 Production of functional *shrikhand*

The functional *shrikhand* was prepared in the experimental learning unit of the Department of Dairy Science and Food Technology, Institute of Agricultural Science, BHU, Varanasi. *shrikhand* sample formation and production procedure were adapted to David (2015). The procedure of manufacturing *shrikhand* is depicted in Figure 1. *Shrikhand* had 34-40% moisture, 43-45% sugar, 4-6% fat, and 10-12% milk solids-not-fat. The current study was used five different treatment combinations in the form of *Shrikhand* constructed on the absence or presence of flaxseed oil powder: control, T1-*shrikhand* 1% (w/v) FSOM; T2-*shrikhand* containing 2% (w/v) FSOM; T3-*shrikhand* containing 1% (w/v) FSO; T4-*shrikhand* containing 2% (w/w) FSO. The standardized milk was heated to 63°C for 30 min before being cooled to 35°C during the manufacturing of functional *shrikhand*. Then, inoculated with lactic starter culture at a concentration of 2% and incubated for 6 h at 35-40^0 C until a firm coagulum (dahi) formed. The dahi was broken and placed to muslin cloth and hanged for 16 h to drain the whey. The coagulum obtained was mixed with 40% sugar, then varied levels of encapsulated FSO and non-encapsulated FSO were incorporated. *Shrikhand* was stored at –10°C in the freezer.

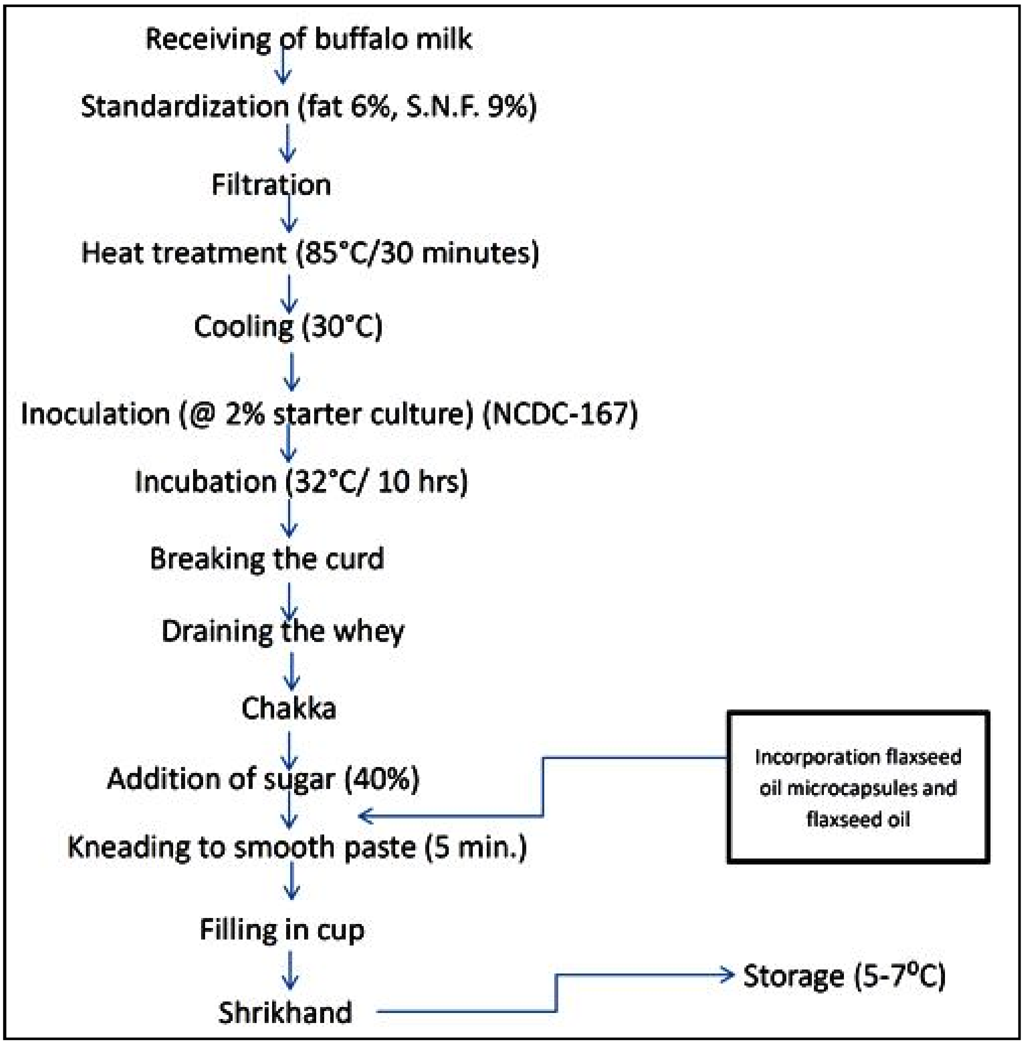

Figure 1: Flow diagram for manufacturing of *shrikhand*.

2.3 Characterization of *shrikhand*

2.3.1 Texture profile of *shrikhand*

The textural properties like springiness, adhesiveness, firmness and hardness were analyzed by the texture profile analyzer (Model TA-XT stable microsystem Plus, UK). Back extrusion probe (A/BE) with a 35 mm disc and extension bar using a 5 kg load cell was used. The tests were conducted in typical back extrusion containers (50 mm in diameter) with a sample size of 30 mm in height and width. The compressive force for the product (*shrikhand*) by the probe was up to the twice distance of 20 mm. For texture analysis, the following circumstances were used: pre-test speed was 3 mm/

sec; test and post-test speeds were 0.5 mm/sec; trigger force was 5.0 g; and time was 5.0 sec for each assessment. The procedure was adopted to Kulkarni *et al.* (2006) with some modification.

2.3.2 Analysis of antioxidant and phenolic attributes of *shrikhand*

For calculation of DPPH scavenging activity, the method of Sutaphanit and Chitprasert (2014) was followed. 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:

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

Where,

A_0 = absorbance of control

A_1 = observed final absorbance of extracted sample at the wavelength of 517 nm.

As a blank, 95 per cent methanol was used.

Total phenolic content was checked by Folin-Ciocalteu method as per Tong *et al*. (2019). Six millilitres of distilled water and 0.5 millilitres of Folin-reagent Ciocalteu's were added in to 0.5 millilitres of supernatants. 1.5 ml of saturated Na_2CO_3 solution was added after 3 min of incubation. The mixes were then incubated at 40°C for 30 min in the dark. The' absorbance of the samples were measured at 765 nm (UV-VIS spectrophotometer) (Shimadzu, Japan). The TPC was measured in milligrammes of gallic acid equivalents per millilitre of sample (mg GAE/ml).

2.3.3 Sensory characteristics of *shrikhand*

The sensory characteristics of the *shrikhand* was carried out in the Department of Dairy Science and Food Technology, BHU, Varanasi, following with the method represented by Gupta *et al.* (2020) with minor modifications. Ten judges (5 females and 5 males) were chosen at random from among faculty, postgraduate students, and research scholars at Department of Dairy Science and Food Technology. The judges were given instruction before the sensory test to familiarize themselves with the procedure. In this study, individuals used a 9-point hedonic scale to rate the *shrikhand*'s sensory characteristics at room temperature (25 ± 2°C). On a scale of 1 to 9, the degree of liking for the samples was scored (1: dislike extremely and 9: like extremely).

2.4 Statistical analysis of *shrikhand*

The complete experiment was repeated three times to measure the physicochemical and sensory properties of *shrikhand*. SPSS version 25 was used to conduct one-way analysis of variance (ANOVA) to examine if there were any significant differences between the samples. Statistically significant differences in variables related to the relevant factor were evaluated at ($p<0.05$).

3. Results

3.1 Antioxidant and phenolic contents of *shrikhand*

The antioxidant and phenolic contents of the *shrikhand* samples incorporated with different levels of FSOM and FSO are shown in Table 1. The antioxidant of *shrikhand* containing 2% FSO was highest value (88.82 ± 0.17) observed as compared to other treatment and lowest value (65.50) observed in control group (Figure 2). Total phenolic content of *shrikhand* containing 2% FSOM was highest (23.30 ± 0.09) as compared to other treatment and lowest value observed in control group (2.10).

Table 1: Antioxidants and total phenolic content analysis of different *shrikhand* samples incorporated with encapsulated powder and non-encapsulated flax seed oil

Treatment	DPPH (% inhibition)	TPC (mg/g GA)
Control	65.50	2.10
T1	86.57 ± 0.09	22.98 ± 0.08
T2	87.59 ± 0.27	23.30 ± 0.09
T3	87.45 ± 0.26	21.69 ± 0.04
T4	88.82 ± 0.17	22.28 ± 0.05
CD @ 5%	0.62	0.24

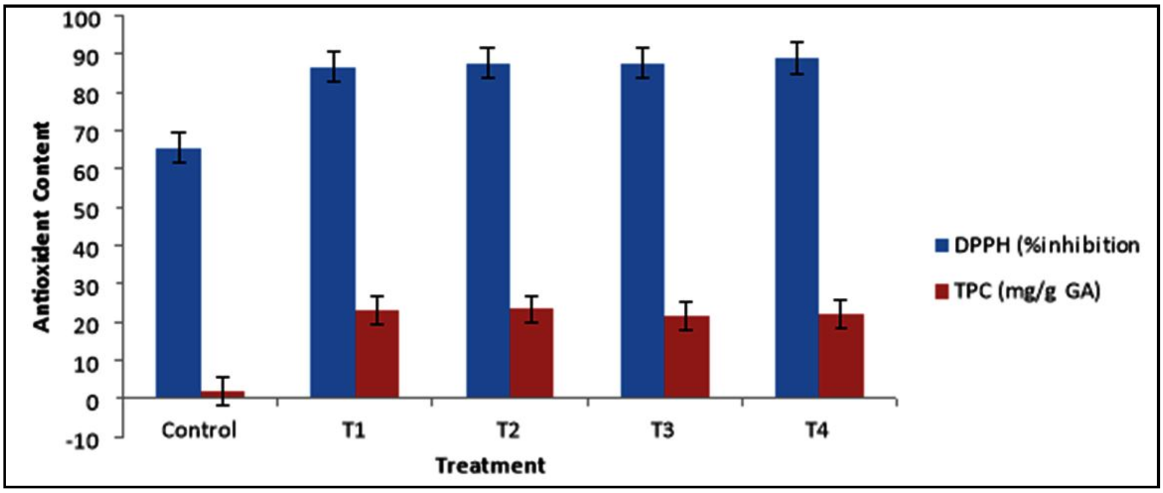

Figure 2: Antioxidants and total phenolic content analysis of different *shrikhand* samples incorporated with encapsulated powder and non-encapsulated flaxseed oil.

3.2 Texture profile analysis of *shrikhand*

The texture profile analysis of *shrikhand* containing different levels of incorporated with FSOM and FSO are shown in Table 2. The firmness of *shrikhand* samples got lowered by enhancing the levels of FSOM. The firmness of the *shrikhand* with FSO *shrikhand* T3, T4 (29.57 ± 0.07, 30.36 ± 0.06) was higher as compared to the firmness of the FSOM *shrikhand* T1, T2 (29.12 ± 0.06, 29.18 ± 0.07). Additional texture properties of *shrikhand* like springiness, and adhesiveness were also changed after adding FSOM and FSO.

Table 2: Texture profile analysis of different *shrikhand* samples containing encapsulated powder and non-encapsulated flaxseed oil

Treatments	Hardness (nM)	Adhesiveness (gs^{-1})	Springiness (mm)	Firmness (g)
control	160.10 ± 0.96	100.77 ± 0.89	2.10 ± 0.11	29.03 ± 0.10
T1	160.58 ± 0.84	99.36 ± 0.42	1.96 ± 0.05	29.12 ± 0.06
T2	163.86 ± 0.45	96.35 ± 0.48	2.02 ± 0.08	29.18 ± 0.07
T3	158.36 ± 0.89	102.35 ± 0.67	1.35 ± 0.03	29.57 ± 0.07
T4	154.67 ± 0.35	104.38 ± 0.50	1.03 ± 0.08	30.36 ± 0.06
CD @ 5%	0.87	1.14	0.091	0.09

3.3 Sensory evaluation of *shrikhand*

The sensory scores acquired for following sensory parameters: color and appearance, body and texture, flavor, mouth feel and overall acceptability of all five *shrikhand* samples are shown in Table 3**.** Slight difference of the sensorial properties was depicted in between the control and FSOM *shrikhand* (Figure 3). The color and appearance attributes of FSOM *shrikhand* (T1 8.06 ± 0.33 and T2 7.85 ± 0.29) and FSO *shrikhand* (T3 7.65 ± 0.37 and T4 7.28 ± 0.40) were not significantly different. The flavor score of the treatment group was slightly lower than the control group. FSOM, *shrikhand* T1, and T2 had flavor scores of 7.92 ± 0.34, and 7.64 ± 0.48, and FSO *shrikhand* T3, T4 had flavor scores of (7.46 ± 0.56, 6.83 ± 0.79), which were lower than those of other treatments. Mouth feels attribute of the control (8.49 ± 0.46) and FSOM *shrikhand* were 7.68 ± 0.42 and 7.31 ± 0.33, respectively. In contrast, FSO *shrikhand* T3 and T4 gives slightly bitter after taste, possessing average rating of 5.89 ± 0.41 and 5.24 ± 0.48, respectively. Treatments T1 and T2 had an overall acceptability score of 7.89 ± 0.31 and 7.62 ± 0.27, respectively, which was higher than other treatments.

Table 3: Sensorial evaluations of different *shrikhand* samples containing encapsulated powder and non-encapsulated flaxseed oil

Treatments	Color and appearance	Flavor	Body and texture	Mouth feel	Overall acceptability
Control	8.58 ± 0.39	8.65 ± 0.44	8.49 ± 0.46	8.78 ± 0.45	8.83 ± 0.41
T1	8.06 ± 0.33	7.92 ± 0.34	7.81 ± 0.33	7.68 ± 0.42	7.89 ± 0.31
T2	7.85 ± 0.29	7.64 ± 0.48	7.57 ± 0.64	7.31 ± 0.33	7.62 ± 0.27
T3	7.65 ± 0.37	7.46 ± 0.56	6.76 ± 0.46	5.89 ± 0.41	5.81 ± 0.83
T4	7.28 ± 0.40	6.83 ± 0.79	6.57 ± 0.62	5.24 ± 0.48	5.29 ± 0.43
CD @ 5%	0.116	0.12	0.073	0.078	0.054

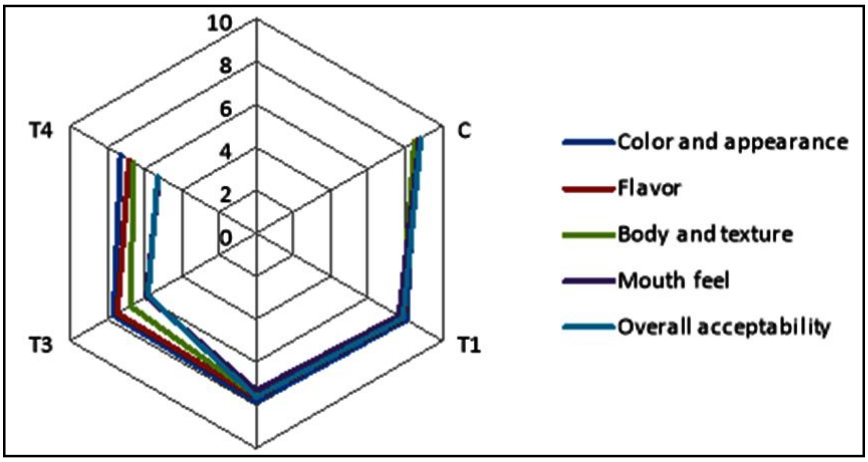

Figure 3: Sensorial analysis of different *shrikhand* samples containing encapsulated powder and non-encapsulated flaxseed oil.

4. Discussion

The antioxidant and phenolic content of FSO *shrikhand* was higher than FSOM *shrikhand* is likely due to the high temperature of the spray dryer used to turn the encapsulated FSO. Generally, the activity of the beneficial components found in flaxseed oil is reduced at temperatures above 60°C (Goyal *et al*., 2014). The findings were compared to a previous study that found increasing the amount of Aronia juice enhanced overall polyphenol and flavonoid content compared to a subset (Nguyen and Hwang, 2016). Furthermore, Servili *et al.* (2011) reported that the total phenolic content of functional milk beverages fortified with olive oil extracts ranged from 53.4-172.5 mg/kg. In another study, jambolan powder products had a lower TPC and DPPH inhibitory activity than jambolan pulp products (Bezerra *et al*., 2015). The antioxidant activity of the yogurt samples incorporated with non-encapsulated and encapsulated olive leaf extract was considerably higher than control yogurt (Tavakoli *et al*., 2018).

The change in textural properties occurs due to the reduced potency of carbohydrates-protein, carbohydrates-lipid interactions. In a similar study, the textural properties of yogurt were increased by adding inulin and its hydrolysates at different concentrations (Gupta *et al*., 2015). Alterations in the sensorial properties were compared with the similar studies evaluated that there was a slight difference between FSOM and FSO *shrikhand* with regards to color and appearance. Flaxseed oil *shrikhand* delivered creamy-yellowish color. Therefore, the incorporation of FSOM had no influence on visual presentation of the *shrikhand*. The color and appearance score findings were agreement with study conducted by Mishra *et al*. (2020). They claimed that the colour attribute of yoghurt infused with encapsulated seed oil was higher than that of yoghurt infused with seed extract. Flaxseed oil *shrikhand* had a similar flavor profile to Gupta *et al*. (2015) oil-enriched *shrikhand*, which reported a flavor score of 6.28 ± 0.45. Kushwaha *et al.* (2019) reported very minor difference in texture and body of *shrikhand*, when mixed with kiwi fruit. The findings of overall acceptance score was in compliance with the result obtained by Jain *et al.* (2003) designated that there was no off-flavor development after the addition of rice bran oil. Hence, the above results indicated that the encapsulation strategy can minimize the unwanted feels (flavor, color, and mouth feel) of the FSO in the food products.

5. Conclusion

In this study, functional *shrikhand* consisting FSO microcapsules was evaluated for functional and sensorial properties. In addition to these findings, the functional dairy industry will benefit from FSOM, since FSOM can be incorporated into a variety of dairy-based products due to its high stability of sensory attributes and bioactive components. Moreover, sensory attributes of *shrikhand* showed that FSOM inclusion did not significantly change the body, texture, color and appearance of *shrikhand*, nor did it influence taste or mouth feel. Additionally, it is concluded that the bioactive compounds from various essential oils can be used in food products like natural bioactive ingredients 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.

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