Utilization of Orange Fiber Powder as a Functional Ingredient in Low-Fat Ice Cream

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Abstract

Low-fat ice cream (LFIC) was prepared by partially replacing skim milk powder with orange fiber powder (OFP) at levels of 2.5 ,1.5, and %3.5 to improve its nutritional value and sensory characteristics. The chemical composition of OFP showed high contents of total solids, ash, protein, carbohydrates, and dietary fiber, including total dietary fiber, soluble dietary fiber, and insoluble dietary fiber, while its fat content was low. The prepared ice cream samples were stored at 18− °C for 30 days and evaluated for microbiological quality, rheological properties, and sensory characteristics. The results indicated significant increases in density and weight per gallon with increasing OFP levels, whereas overrun decreased as the level of OFP increased. Microbiological analyses revealed reductions in total bacterial counts and yeast and mould counts with increasing OFP levels and storage time. Control samples showed higher microbial counts compared with OFP-fortified samples. Psychrotrophic bacteria and coliform groups were not detected in any treatment. Sensory evaluation showed that LFIC containing OFP had slightly lower overall scores than the control samples. However, fresh samples fortified with %1.5 OFP achieved the highest sensory scores among the OFP treatments, whereas samples containing %3.5 OFP stored for 30 days received the lowest scores.

Key wards: Low-fat ice cream, Orange fiber powder, Sensory quality, Dietary fiber.

ملخص

تـم تحضير ألياف البرتقال المجفف من قشـر البرتقـال الناتج من صناعة العصير لإسـتخدامه فـي صناعة الأيس كريـم منخفض الدهـن ، حيث تـم تحضيـر الايس كريـم منخفض الدهن باسـتبدال نسـبة مـن اللبن الفـرز المجفف بألياف البرتقال المجفف بنسـبة 1.5 ، 2.5 ، 3.5% بهدف تحسـين القيمـة الغذائية والخـواص الحسـية للمثلوجـات ، وتم إضافة هذه الألياف أثناء بسـترة المخلـوط ، وقد تم تخزين المنتـج النهائي على درجـة 18 ْم تحت الصفر لمـدة 30 يوم ، وقد أوضحـت النتائج المتحصل عليها مـا يلي :-

- كان محتوى أليـاف البرتقال المجفف عاليا في كلا مـن الجوامد الكلية والرمـاد والبروتين والكربوهيـدرات والألياف الغذائيـة الكلية والذائبة والغيـر ذائبة ومنخفضة في نسـبة الدهن .
- كان هنـاك زيـادة فـي كلا مـن الكثافـة ووزن الجالـون بالرطل في المنتـج النهائـي بزيادة نسـبة الأليـاف المضافة .
- كان هناك زيـادة معنوية في كلا من الكثافـة ووزن الرطل بالجالون بزيادة نسـب أليـاف البرتقال المجفـف ، وكانت عينـات المقارنة أقل من المعامـلات المحتوية على ألياف البرتقـال المجففة .
- كان هنـاك تناقـص معنـوي فـي نسـبة الريع بزيـادة نسـبة ألياف البرتقـال المجففـة ، وكانت نسـبة الريع فـي عينـات المقارنة أعلى منهـا فـي المعامـلات المحتوية علـى أليـاف البرتقـال المجففة .
- كان هنـاك إنخفاض في كلا مـن العدد الكلي للبكتريـا وأعداد الخمائر والفطريـات بزيادة نسـبة الأليـاف المجففـة وبزيادة مـدة التخزين حتـى ٣٠ يـوم في جميـع المعامـلات ، وكانـت عينـات المقارنة أعلى عنها فـي المعامـلات المحتوية على أليـاف البرتقـال المجففة .
- عدم وجـود كلا من البكتريا المحبة للبـرودة ومجموعة بكتريا القولون في جميع المعاملات
- كانـت المعاملات المحتويـة على أليـاف البرتقال المجففـة أقل في درجـات التقييـم الحسـي الكلي عنها فـي عينـات المقارنـة ، وكانت

العينات الطازجة المحتوية على ألياف البرتقال المجففة أعلى عنها في العينات المخزنة .

- حصلت العينات الطازجة المحتوية على ١,٥٪ ألياف البرتقال المجففة على أعلى درجات التحكيم الكلي ، بينما حصلت العينات المحتوية على ٣,٥٪ ألياف برتقال مجففة والمخزنة لمدة ٣٠ يوم على أقل الدرجات .

الكلمات الدالة: قشر البرتقال المجفف، الايس كريم منخفض الدهون، الجودة الحسية، الألياف الغذائية.

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Introduction

In recent years, considerable attention has been directed toward the valorization of agro-industrial by-products as functional ingredients in food systems due to their potential nutritional, technological, and environmental benefits. The sustainable utilization of food processing residues has gained increasing interest as part of circular bioeconomy strategies and waste reduction in the food industry (Nirmal et al., 2023; Sharma et al., 2017). Among these by-products, residues generated from citrus processing have attracted particular interest because they represent an inexpensive source of functional ingredients in food formulations (Csapo and Nemethy, 2018; Elleuch et al., 2011). Orange processing, in particular, generates large quantities of by-products such as peels, pulp, and seeds, which constitute a significant portion of the total fruit mass. These residues represent an abundant source of dietary fiber and various phytochemicals, including flavonoids, phenolic acids, carotenoids, and vitamin C, which are widely recognized for their antioxidant properties (Eddour et al., 2025; Manthey and Grohmann, 2001). In addition, these by-products contain both soluble and insoluble dietary fibers that contribute to several functional and physiological benefits. Dietary fiber plays an important role in maintaining human health by improving bowel function and reducing the risk of several chronic diseases, such as cardiovascular diseases, type 2 diabetes, obesity, and hypercholesterolemia (Hauner et al., 2012, Marín et al, 2007).

From a sustainability perspective, the utilization of orange processing residues, particularly orange fiber, represents an effective strategy for reducing agro-industrial waste while producing value-added food ingredients. Large quantities of orange by-products are generated annually by the juice industry, and their incorporation into food systems not only minimizes environmental impact but also supports the development of sustainable and circular production systems (Laufenberg et al., 2003; Olmedo-Galarza et al., 2025; Sharma et al., 2017).

From a food chemistry perspective, in addition to their nutritional benefits, dietary fibers exhibit important technological properties such as water-holding capacity, viscosity enhancement, oil-binding ability, and gel-forming capacity. These characteristics make dietary fibers suitable as fat replacers capable of mimicking the functional properties of fat without compromising product quality in reduced-fat formulations, significantly influencing the physicochemical and rheological properties of food products (Elleuch et al., 2011; Guichard, 2002; Wu et al., 2025). The incorporation of orange fiber into low-fat food products can therefore enhance texture, stability, and nutritional quality while simultaneously promoting the sustainable reuse of food processing residues (Sharma et al., 2017).

Low-fat ice cream products often suffer from weak flavor perception and poor texture due to the reduced fat content. Therefore, dietary fibers, including orange fiber, represent suitable candidates as fat replacers, capable of mimicking the functional properties of fat without compromising product quality, making them an important focus of research in dairy technology (Guichard, 2002; Elleuch et al., 2011). The incorporation of dietary fibers can enhance both the nutritional and technological properties of low-fat ice cream, while high-fiber and low-fat formulations may also contribute to reducing the risk of cardiovascular diseases, obesity, colon cancer, and other chronic disorders (Obaid, 2021).

The incorporation of orange fiber into low-fat ice cream formulations represents a promising strategy to simultaneously improve nutritional quality, enhance functional properties, and promote the sustainable utilization of food processing by-products. In addition, orange fiber can improve body and texture, enhance melting resistance, reduce ice recrystallization during storage, and increase the overall stability of the frozen product. Moreover, as a functional ingredient, dietary fibers can partially replace fat in low-fat dairy products, providing technological and nutritional benefits without compromising product quality (Crizel at al, 2014 ,2013; Dervisoglu and Yazici, 2006).

The utilization of orange fiber in the manufacture of low-fat ice cream offers a promising strategy to improve product quality while supporting environmentally sustainable food production. Therefore, the aim of this study was to investigate the effect of orange fiber powder, as a natural source of dietary fiber, on the rheological, microbiological, and sensory properties of low-fat ice cream.

Materials and methods

Materials:

Fresh buffalo's milk: was obtained from the Herd of the Animal Production Department, faculty of Agriculture, Al-Azhar University (Branch of Assiut).

Chemicals: were of analytical grade supplied by BDH, Sigma chemical companies.

Skim milk powder, sugar and vanillin: were purchased from the local market

Dietary fiber from fruits sources (Orange): They were obtained from local market.

Stabilizers: Indian carboxy methyl cellulose (CMC) high viscosity minimum assay %95.5 was obtained from local market.

Methods:

❖ ***Preparation of orange fibers powder (OFP):***

The orange fibres were produced from the by-products of orange juice production; the raw material are collected in a single week and stored at 18-˚C for further use. The fibre samples were thawed at room temperature, manually cut into pieces (1 cm2) and washed and sanitized in a sodium hypochlorite solution (150 mg/L) for 10 min. The samples were dehydrated in a tray dryer at 60˚C until the weight remained constant, approximately 4 h. After cooling to room temperature (25˚C), the dried product was ground in a mill (Arbel, model MCF55, Brazil). The milled fibre was separated using sieves for particle size analysis (Bertel, Brazil); the separated particles were smaller than 125 mm (mesh 115). The fibre was packed in a vacuum sealer (Fastvac, model F

200, Brazil) and stored in the dark at room temperature (25˚C). They were adopted according to Crizel et al. (2013).

❖ ***Preparation of Low-Fat Ice Cream Mix:***

The mixes of LFIC consisted of %3 fat, %14 SNF, %15 sugar, %0.3 carboxy methyl cellulose and %0.1 vanillin. LFIC by OFP was prepared by replacing skimmed milk powder with OFP. They were made by combining different levels of OFP during pasteurization of mix with ratio 5. 2 ,1.5 and %3.5. The final products were stored at 18-°C for 30 days and evaluated for its physico-chemical composition, microbiological analyses, rheological properties and sensory evaluation.

Chemical Analysis:

Total solids, fat content, protein content in milk and orange fiber were adopted according to **Ling (1963).**

- Dietary fiber composition:

Total dietary fiber, soluble and insoluble, was estimated according to the method mentioned **(AOAC, 2008).**

Total carbohydrate and ash contents were determined as reported by the **AOAC (1984).**

- Rheological properties:

Density: Density was calculated using the regular equation as follows:

$$\text{Density (g/cm}^3\text{)} = \frac{\text{Weight}}{\text{Volume}}$$

Weight per gallon in pounds: It was directly determined according to Burke (1947) by multiplying the density of the resultant ice

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product by the factor 8.34.

The relative viscosity of ice mix: It was determined according to Arbuckle (1986).

Overrun: It was determined according to (Sommer, 1951).

Melting resistance: It was determined according to Arbuckle (1986).

The measurements of all previous tests were done in triplicate.

- *Microbiological Analyses:*

The total bacterial count was determined according to **Marshall (1992).** Coliform bacteria and Yeasts & Moulds were enumerated according to **IDF (1985a)** and **IDF (1985b)**; respectively. Psychrotrophic bacterial count is estimated by plating the milk using the SPC procedure and incubating for 10 days at °7C **(Marshall, 1992).**

- Organoleptic properties: It was assessed by members of the department according to following score card **(Marshall and Arbuckle, 1996).**

- *Statistical Analyses:*

Analysis of variance was performed on the data using the software program; The SAS system for windows, release 8.02 TS level 02 M0, SAS Institute Inc., **Cary, NC, USA (SAS, 1999).**

The measurements of all previous tests were done in triplicates.

Results and discussion

In the present study, the use of orange fiber powder (OFP) for the production of low-fat ice cream (LFIC) was evaluated. LFIC was prepared by incorporating different levels of orange fiber powder (OFP), replacing skimmed milk powder at ratios of ,%1.5 %2.5, and %3.5. The final products were stored at °18−C for 30 days and subsequently evaluated for their microbiological characteristics, rheological properties, and sensory attributes.

The chemical composition of OFP:

Data presented in Table 1 illustrate the physico-chemical composition of OFP. The obtained data revealed that, OFP had high total solids, ash, protein, carbohydrates, total dietary fiber (TDF), soluble dietary fiber (SDF) and insoluble dietary fiber (IDF). Whilst, it low of fat content. These results near accordance of data reported by Crizel et al. (2013).

Table 1: Chemical analyses of OFP.

Components (%)	Orange fiber
Moisture	5.35
Ash	3.16
Protein	9.22
Fat	2.14
Carbohydrates	63.80
TDF	45.40
SDF	12.20
IDF	33.30

The using of OFP in LFIC making:

Dietary fibers play an important role in human health. During normal metabolism, the OFP are maintained in equilibrium.

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Table 2: Ingredients used to prepare LFIC mix (100 g mix).

Product / Ingredient	C	Treatment		
		T1	T2	T3
Fresh buffaloes milk	46.06	45.65	46.13	46.10
Skim milk powder	10.82	10.84	10.78	10.79
Sugar	15	15	15	15
Stabilizer	0.3	0.3	0.3	0.3
Vanillin	0.1	0.1	0.1	0.1
Water	27.81	26.70	25.28	24.29
OFP	-	1.5	2.5	3.5

C: control LFIC with vanilla; TI, T2, T3: LFIC with 2.5 ,1.5 and %3.5; respectively.

The aim of the present study was to study the effect of OFP with ratio; 2.5 ,1.5 and %3.5. Selection ingredients of LFIC mixes were carried out according to the required amounts. These calculations are tabulated in Table 2.

- LFIC mix properties with OFP:

LFIC mix samples were prepared for testing the following characteristics: relative viscosity, density and weight per gallon.

Table 3: Effect of different levels of OFP on relative viscosity, density and weight per gallon of LFIC mix.

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Properties	C	Treatment		
		T1	T2	T3
The relative viscosity	1.460[d]	5.084[c]	8.474[b]	13.559[a]
Density (g/cm3)	1.250[d]	1.303[c]	1.350[b]	1.450[a]
Weight per gallon (lb)	10.424[d]	10.866[c]	11.258[b]	12.092[a]

The data presented in Table 3 shows the physical properties of LFIC mix prepared by using three different levels of OFP. The obtained data in the same Table observed that, there were increases of relative viscosity and density as well as weight per gallon in pounds with increasing of OFP percentages. In addition, the relative viscosity, density and weight per gallon in pounds in LFIC mix with OFP were higher than that of control samples. These results are in agreement with those obtained by Crizel et al. (2014).

Microbiological analysis of LFIC mix:

Data presented in Table 4 illustrates the total bacterial, psychotrophic bacteria, coliform group and yeast & moulds counts of LFIC mix with OFP.

Table 4: Effect of different levels of OFP on microbiological analysis (Log CFU/ml) of LFIC mix.

Microbial type	C	Treatment		
		T1	T2	T3
Total bacterial	4.37	4.36	4.36	4.35
Psychrotrophic	ND*	ND	ND	ND
Coliform group	ND	ND	ND	ND
Yeast & Moulds	1.43	1.42	1.42	1.40

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ND*: Not detected

The data showed that, the total bacterial and yeast & moulds counts of LFIC mix were affected by addition of OFP. Generally, the data revealed that there were slight decreases of total bacterial and yeast & moulds counts in LFIC mix with increasing of OFP in most treatments. This may be due to that the effect of OFP on them. Moreover, control samples had higher counts of total bacteria and yeast & moulds than that of LFIC mix with OFP in all treatments. On the other hand, the data observed that there were not detected of psychotrophic bacteria and coliform group counts in all treatments. This might be due to high hygienic condition during preparing LFIC mix. These results are disagreement with those obtained by Mansour et al. (2015).

- Resultant LFIC:

Density, weight per gallon and over run:

The data presented in Table 5 represent the density, weight per gallon and over run of resultant LFIC prepared by using three levels of OFP. The obtained data in the same Table observed that, there were increases significantly of density and weight per gallon in pounds with increasing of OFP; while, the control samples had lower values than that of LFIC with OFP. These results are in agreement with those obtained by Mansour *et al.* (2015).

Table 5: Effect of different levels of OFP on density, weight per gallon and over run of LFIC.

Components	Treatment			
	C	T1	T2	T3
Density (g/cm3)	0.625[d]	0.966[c]	1.066[b]	1.212[a]
Weight per gallon (lb)	5.212[d]	8.056[c]	8.890[b]	10.113[a]
Over run	50.000[a]	25.831[b]	20.987c	16.091[d]

Regarding overrun, the data in the same Table represent that it was decreased significantly with increasing OFP ratios; while, the control samples had higher values than that of LFIC with OFP. These results are in agreement with those obtained by Mansour et al. (2015).

Melting resistance:

The melting resistance of the samples was taken from the hardened LFIC. The data of melting resistance are shown in Table 6.

Table 6: Effect of different levels of OFP on melting resistance of LFIC.

Melting resistance (%)	Treatment			
	C	T1	T2	T3
After: 10 min	14.00	3.66	1.88	2.77
20 min	46.00	11.85	12.00	11.00
30 min	65.00	24.77	22.35	20.66
40 min	82.00	39.75	38.00	30.95
50 min	FM*	71.44	63.15	55.75

The results showed that, the melting after 10 min at 37°C being

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1.88 ,3.66 and %2.77 for the LFIC containing 2.5 ,1.5 and %3.5 OFP; respectively. Whilst, these values were 39.75 ,82.00 and %30.95 after 40 min for the LFIC containing 2.5 ,1.5 and %3.5 OFP; respectively.

Some researchers were used dietary fibers as functional foods, where Abo Srea et al. (2017) can be used free fat, emulsifying and stabilizers ice cream-like using konjac dietary fiber as the optional level (%0.3) instead of full fat and commercial emulsifying and stabilizers with a decrease in the economic cost up to %41; and melting properties was significant differences among most all treatments and control.

Microbiological analysis:

Data presented in Table 7 illustrates the total bacterial, psychotrophic bacteria, coliform group and yeast & moulds counts of LFIC with different levels of OFP during storage periods at 18-˚C for 30 days.

Table 7: Effect of different levels of OFP on microbiological analysis (Log CFU/ml) of LFIC.

Microbial type	Storage (days)	Treatment			
		C	T1	T2	T3
Total bacterial	Fresh	4.37	4.37	4.36	4.35
	15	4.33	4.30	4.25	4.15
	30	4.30	4.25	4.24	4.08
Psychrotrophic	Fresh	ND	ND	ND	ND
	15	ND	ND	ND	ND
	30	ND	ND	ND	ND

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Microbial type	Storage (days)	Treatment			
		C	T1	T2	T3
Coliform group	Fresh	ND	ND	ND	ND
	15	ND	ND	ND	ND
	30	ND	ND	ND	ND
Yeasts & Moulds	Fresh	1.41	1.41	1.39	1.38
	15	141	1.40	1.38	1.37
	30	1.39	1.39	1.37	1.36

The data showed that, there were decreases of total bacterial and yeast & moulds counts in LFIC with increasing of OFP and with increasing of storage period up to 30 days in all treatments. Moreover, the control samples had higher counts of total bacteria and yeast & moulds than that of LFIC with OFP in most treatments. These results are in agreement with those obtained by Mansour et al. (2015).

On the other hand, the data observed that there were not detected of psychotrophic bacteria and coliform group counts in all treatments. This might be due to high hygienic condition during preparing LFIC mix. These results are in agreement with those obtained by Mansour et al. (2015).

Organoleptic properties:

Scoring for LFIC samples was carried out by 12 of staff members of the dairy department according to the scoring sheet previously mentioned in the methodology and based on that described by Marshall and Arbuckle (1996). Flavor was given 30 points, body & texture 30 points, melting quality 20 points and appearance 20 points.

Table 8: Effect of different levels of OFP on organoleptic properties of LFIC.

Properties	Storage (days)	Treatment			
		C	T1	T2	T3
Flavor (30)	Fresh	26.50	25.75	22.50	21.25
	15	27.00	23.25	19.75	17.75
	30	26.00	22.75	17.75	16.50
Body & texture (30)	Fresh	27.00	25.50	24.75	23.00
	15	27.75	23.50	20.25	18.00
	30	25.75	21.00	16.50	16.00
Melting quality (20)	Fresh	16.50	17.00	15.75	14.50
	15	18.25	16.00	14.5	13.75
	30	17.25	16.00	15.50	15.25
Appearance (20)	Fresh	18.75	17.50	16.50	15.50
	15	19.00	16.25	15.00	14.50
	30	18.50	17.50	16.00	14.00
Overall scores (100)	Fresh	88.75	85.75	79.50	74.25
	15	92.00	79.25	69.50	64.00
	30	87.50	77.25	65.75	61.75

Data in Table 8 showed that, the organoleptic properties such as; flavor, body & texture melting quality and appearance of LFIC were affected by addition of OFP and during storage periods at 18-°C up to 30 days. They summarize scoring points of LFIC samples produced at different levels of OFP during storage periods at 18-°C up to 20 days.
The data observed that, LFIC with OFP had lower total scores than that of control samples in all treatments. In addition, fresh

LFIC with OFP had higher scores than that of other treatments. Moreover, the data showed that the fresh samples with %1.5 OFP had superior scores among all LFIC treatments with OFP. Whilst, the samples with %3.5, stored at 30 days had the lower scores among all LFIC treatments with OFP.

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