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Functional, Physicochemical, Rheological, Microbiological, and Organoleptic Properties of Synbiotic Ice Cream Produced from Camel Milk Using Black Rice Powder and *Lactobacillus acidophilus* LA-5

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Citation: Elkot, W.F.; Ateteallah, A.H.; Al-Moalem, M.H.; Shahein, M.R.; Alblihed, M.A.; Abdo, W.; Elmahallawy, E.K. Functional, Physicochemical, Rheological, Microbiological, and Organoleptic Properties of Synbiotic Ice Cream Produced from Camel Milk Using Black Rice Powder and *Lactobacillus acidophilus* LA-5. *Fermentation* **2022**, *8*, 187. https://doi.org/10.3390/fermentation8040187

Academic Editor: Senaka Ranadheera

Received: 23 March 2022
Accepted: 9 April 2022
Published: 15 April 2022

Abstract: Camel milk has become more popular among customers in recent years as a result of its therapeutic effects. In many parts of the world, it is considered one of the primary components of human nutrition. The present study aimed to develop a novel synbiotic ice cream from camel milk formulated with black rice powder (BRP) and investigate the viability of probiotic bacteria (*Lactobacillus acidophilus* LA-5) during the storage period (60 days). Skim milk powder was replaced by BRP at levels of 0, 25, 50, and 75%. The produced ice cream was examined for some physicochemical, rheological, microbiological, and sensorial properties. The obtained results indicated that the incorporation of BRP into ice cream blends resulted in significant increases in the overrun, viscosity, and melting resistance of ice cream samples ($p < 0.05$). However, the freezing point decreased with increasing the proportion of BRP in the blend. The sensory evaluation results showed that the most acceptable treatments were those formulated with 25% and could be increased to 50% of BRP with no significant differences. The incorporation of BRP improved the viability of *Lactobacillus acidophilus* LA-5 in ice cream samples over 60 days of storage. Collectively, a synbiotic camel milk ice cream formulated with black rice powder was produced that, in turn, enhanced the physicochemical and rheological properties of ice cream samples and produced a significant protective effect on the viability of probiotic bacteria.

Keywords: black rice powder; camel milk; synbiotic; *Lactobacillus acidophilus* LA-5; incorporation

1. Introduction

Camel milk varies from other milks in terms of chemical composition, since it contains higher amounts of vitamins, minerals, and insulin. On the other hand, it contains lower sugar, cholesterol, protein, and therapeutic properties [1]. Based on the concept of functional foods, which add components with additional health advantages to diets, camel milk could be considered a functional food according to its important nutritional and functional values and may provide specific health benefits as a result of the bioactive compounds [2]. Dairy products have long been associated with health benefits, due to their content of bioactive components, organic acids, oligosaccharides, proteins, and easily absorbable minerals [3]. They continue to be the main vehicle for the dietary administration of probiotics and prebiotics. Synbiotics are a type of synergism in which probiotics and prebiotics are combined in a single diet to boost probiotic bacteria survival during storage and passage through the intestinal tract, hence promoting the selective development of indigenous gut bacteria [4]. Ice cream is one of the world's most popular frozen desserts today, and its global consumption is on the rise. Ice cream, generally defined as a frozen mixture of milk, dairy products, and sugar, is considered one of the most popular desserts in the world [5]. Sayar et al. (2022) [6] produced functional ice cream from camel milk by using blueberry fruit at different concentrations. Additionally, camel milk can be used in many recipes that are beneficial to consumers for prevention and as a complete adjuvant alongside medicine in the treatment of a variety of diseases in different locations around the world [7].

The manufacturing of functional foods has received a lot of attention in recent years [8–12]. The primary goal of functional foods is to incorporate beneficial microorganisms or compounds into the body through dietary consumption on a regular basis. The combination of probiotics and prebiotics will produce synbiotic products that will offer health benefits to consumers. Synbiotic formulations containing food products are widely used for therapeutic food production. *Lactobacillus acidophilus* LA-5 (*L. acidophilus* LA-5) is a probiotic strain that has been known to have benefits for gastrointestinal and digestive health and therapeutic characteristics [13]. Furthermore, *Lactobacillus acidophilus* LA-5 has previously been successfully used in functional ice cream manufacturing, despite the challenges associated with the manufacturing process, including freeze injuries to probiotics [14,15].

The global demand for prebiotics has significantly increased in the last few years, due to their various nutritional characteristics [16]. Black rice (BR) (*Oryza sativa* L.) is a unique rice variety with an endosperm covered by black bran. The rice endosperm is a translucent gray to almost black, and when cooked, it turns deep purple. The unusual color of black rice and its sweet, nutty taste make it popular in many Asian countries. Anthocyanin, particularly cyanidin 3-glucosidase and peonidin 3-glucosidase, is responsible for the black rice color [17]. Reportedly, these bioactive compounds have strong scavenging ability and antioxidant effects, which help to lower cholesterol levels and minimize the chance of cardiovascular diseases and cancers [18]. BR also contains many bioactive compounds, such as protein, crude fiber, total carbohydrates, and minerals, with an attractive purple color, making it a valuable component in the dairy industry [19]. The anthocyanins and anthocyanin monomers from black rice had prebiotic activity, and they were metabolized into several small molecules by *Bifidobacteria* and *Lactobacillus* [20]. Thus, food supplementation with black rice will have a great effect on human health [19,21]. BR is usually consumed with the bran because of the existence of anthocyanin, and it is offered as unmilled rice. After cooking, the color of BR becomes purple with a glossy indigo finish and has a mild nutty taste with a smooth and firm texture [22]. Even though rice and rice bran incorporation into functional dairy products can be challenging, the development of rice-incorporated synbiotic dairy products with low retrogradation properties has previously been reported [23].

Consumers are now interested in low-cost healthy dairy products (functional dairy products). The preparation of functional ice cream has been investigated by several investigators, including the following: Darwish et al. (2016) [24] studied the impact of adding Jerusalem artichoke on the functional properties of ice cream. El-Samahy et al. (2015) [25] produced a low-fat ice cream with improved functional and rheological properties, using prickly pear fruits. Elkot et al. (2017) [26] processed an ice milk supplemented with sebesten fruits as functional ingredients rich in natural antioxidants and high levels of unsaturated fatty acids in the manufacture of ice milk. To the best of our knowledge, there are no publications regarding the enrichment of camel-milk ice cream with black rice. Therefore, the aim of this study was to produce a novel functional ice cream from camel milk and evaluate the influence of supplementation with black rice powder on the physicochemical, rheological, and sensory properties of camel milk ice cream and the impact of different levels of black rice powder on the probiotic culture survival during the frozen storage at –18 °C for 60 days.

2. Materials and Methods

2.1. Materials and Reagents

Fresh raw camel milk was provided by a camel farm in Aswan Governorate, Egypt (containing 3.5% fat, 3.2% protein, and 0.89% ash). Milk samples were immediately kept refrigerated until use. Fresh cream (25% milk fat), sugar, skimmed-milk powder (97% TS), and gelatin were bought from a local market. The BR sample was obtained from the Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt. BR was milled by using Cyclotec milling (Cyclotec^{TM} 1093, Foss, Sweden) and sieved by using a 60-micrometer sieve. The obtained black rice powder (BRP) was used in the ice cream mix. Freeze-dried starter cultures of *L. acidophilus* LA-5 were obtained from Chr. Hansen dairy cultures, Denmark. Cultures were used in a freeze-dried direct vat set. All reagents and chemicals were analytical grade and purchased from Sigma-Aldrich Co. (St. Louis, MO, USA).

2.2. Preparation of Basic Ice Cream Mixtures

Different treatments of ice cream mixes were prepared in duplicate batches in the laboratory of the Department of Dairy Science & Technology, Faculty of Agriculture & Natural Resources, Aswan University, Aswan, Egypt, as follows: control, ice cream made without any replacements; T1, ice cream mix formulated with 25% BRP; T2, ice cream mix formulated with 50% BR; and T3, ice cream mix formulated with 75% BRP (T3).The BRP was added as a replacement agent for skim milk powder at the mentioned levels, meaning that all formulas have the same total solids. The basic ice cream mix was produced based on the Egyptian standards of ice cream, and the formulas are illustrated in Table 1. The formulated ingredients were mixed and dissolved for 2 h at room temperature and then preheated at 40 °C for 5 min. The formulations were pasteurized at 85 °C for 10 min and then transferred to glass containers and cooled to a temperature of 37 °C. Then *L. acidophilus* LA-5 was inoculated in ice cream mixes and incubated at 37 °C until the pH reached 5.80. The mixtures were then frozen for 20 min in a batch freezer. The ice cream samples were packed into plastic containers (100 mL), at a temperature of 5 °C, and stored at 18 °C until analysis.

Table 1. Ice-cream-mix formulations.

Ingredients	Amount/100 kg			
	Control	**T1**	**T2**	**T3**
Whole camel milk	46	46	46	46
Cream	32.5	32.5	32.5	32.5
Skim milk powder	5.9	4.43	2.95	1.48
Sucrose	15	15	15	15
Vanilla flavor	0.1	0.1	0.1	0.1
Gelatin	0.5	0.5	0.5	0.5
BR powder	0	1.47	2.95	4.42
Total	100	100	100	100

2.3. Chemical Analysis of Black Rice Powder (BRP)

2.3.1. Proximate Analysis

Moisture, fat, ash, and protein were estimated by using the methods of AOAC [27]. Carbohydrates were calculated by difference. Inductivity coupled plasma (Perkin-Elmer Plasma 400 ICP Emission) was used for the determination of zinc, manganese, and iron contents.

2.3.2. Determination of Total Phenolic Compounds (TPCs) and Antioxidant Scavenging Activity (AA)

Sample (5 g) was mixed with 50 mL of 50% ethanol, stirred for 1 h, and then filtered by using Whatman No. 1. The TPCs were determined in the ethanolic extract by using the method of Amin et al. (2004) [28]. Antioxidant activity was determined by using DPPH assay according to the method of Burits and Bucar (2000) [29]. The scavenging activity was estimated by using the following formula:

$$\text{DPPH radical—scavenging activity (\%)} = [(1 - A_1/A_0) \times 100] \quad (1)$$

where A_0 is the OD of the control, and A_1 is the OD of the sample.

2.3.3. Determination of Total Anthocyanins

The anthocyanin extract was prepared and determined according to Wrolstad et al. (2005) [30]. A sample (0.5 g) was mixed with 15 mL of extraction solvent (0.01% v/v HCl in methanol), and the pigments were extracted by homogenization. After filtration of the extract, the optical density (OD) was measured at 530 nm against a blank, which was the extraction solvent. Results were expressed as mg of cyanidin-3-glucoside/100 g.

2.4. Chemical Composition Analysis of the Synbiotic Ice Cream

2.4.1. Proximate Composition

For each parameter, the mean values of three independent replicates were analyzed. Total solids, protein, fat, ash, and fiber were assayed based on the recommended methods of AOAC [27]. The carbohydrate content was determined by subtracting the sum of fat, protein, lactose, and ash from total solids. The content of total soluble solids (TSSs) was determined by using Abbe refractometer (Hamburg, Germany) at 20 °C, and the values were expressed as Brix.

2.4.2. Determination of the Physicochemical and Rheological Properties of Synbiotic Ice Cream

The ice cream samples were examined for physicochemical properties after a 24 h storage period. Acidity and pH values were estimated according to the methods of AOAC [27]. The freezing point was determined by using a specific low-temperature thermometer. According to Marshall et al. (2003) [31], mix freezing points were calculated by a formula method, overrun was estimated by using a 100 mL standard cup at 25 ± 1 °C, and the difference in volume between the resultant ice cream and the original mix was as follows:

$$\%Overrun = \frac{(\text{Weight of ice cream mix} - \text{Weight of same volume of ice})}{\text{Weight of ice cream mix}} \times 100 \quad (2)$$

The methodology proposed by Baú et al. (2014) [32] was used to determine viscosity. After 20 h, the viscosity of the refrigerated ice cream mixture was measured by using a viscometer (Brookfield RH, USA) at 2.5 rpm after 30 s of rotation at 25 ± 1 °C. Melting rate was measured by placing a 60 g ice cream sample on a wire mesh (1 mm) at 25 ± 1 °C, over a beaker. After 90 min, both the melted and un-melted ice cream were weighed according to the method adopted elsewhere [33]. The melting rate was calculated as the weight of drip vs. time (min). Analysis was performed in triplicate after 1 day. The color of ice cream enriched with BRP was measured by using a light reflectance spectrophotometer (Mionolta, CR 300, Osaka, Japan). Measurements were recorded as L* to express (lightness), +a* (redness) and +b* (yellowness) based on CIE (Commission Internationale de I'Eclairage) color coordinates.

2.4.3. Microbial Analysis of the Synbiotic Ice Cream

Total bacterial counts were determined according to the method of BAM [34]. The plates were anaerobically incubated at 37 °C for 48 h. *Lactobacillus acidophilus* LA-5 was counted by using the *Lactobacillus* selective agar and 0.2 Oxgell (Merck, Darmstadt, Germany). The incubation was at 37 °C for 48 h. The samples were evaluated during storage at −18 °C for 60 days for pH, acidity, total bacterial count, and viability of *L. acidophilus*.

2.4.4. Sensory Evaluation

All the ice cream samples were sensory evaluated for flavor, body and texture, melting properties, and color by 15 panelists from the staff. All the panelists had previous experience in ice cream evaluation. A hedonic scale from 1 to 10 was used. Scale 1 refers to extreme dislike, and scale 10 refers to extreme liking. Overall acceptability was calculated from the total score of the judged attributes.

2.4.5. Statistical Analysis

Significant differences between the samples were detected by using analysis of variance (ANOVA) and Duncan's multiple range tests. The level of $p < 0.05$ was used to define the significant differences. The SPSS program was used to conduct all of the analyses (version 20 SPSS Inc.).

3. Results and Discussion

3.1. Chemical Composition and Bioactive Components of Black Rice Powder (BRP)

The chemical composition of BRP is illustrated in Table 2. BRP had a moisture content of 10.85%, with carbohydrates accounting for the majority of its dry matter (74.34%). It contains a good protein content (8.47%), with a lower fat content (2.49%) and crude fiber content (1.26%). The gross composition of BRP was similar to the findings of a previous study for Chinese black rice [35]. In addition, BRP has appreciable amounts of mineral salts, such as manganese, iron, and zinc (2.73, 1.42, and 3.53 mg/100 g), respectively. Similar findings were found for these minerals in black rice, as reported elsewhere [36].The TPC content of BRP was 473.6 mg/100 gm. The total anthocyanins were 132.2 mg of cyanidin-3-glucoside/100 g.

Table 2. Chemical composition, phenolic compounds, flavonoids, and anthocyanin's of black rice powder.

Ingredient	Concentration
Moisture (%)	10.85 ± 0.21
Total carbohydrates (%)	74.34 ± 0.41
Crude protein (%)	8.47 ± 0.05
Crude fat (%)	2.49 ± 0.16
Total dietary fiber (%)	1.26 ± 0.02
Ash content (%)	2.59 ± 0.03
Zinc content (mg/100 g)	3.53 ± 0.01
Iron content (mg/100 g)	1.42 ± 0.00
Manganese content (mg/100 g)	2.73 ± 0.02
Total phenolic compounds (mg GAE/100 g)	473.6 ± 3.17
Total Scavenging activity (DPPH, %)	56.15 ± 0.06
Total anthocyanins (mg cyanide 3-glucoside/100 g)	132.2 ± 1.21
Color readings	
L *	63.33 ± 0.00
a *	8.41 ± 0.05
b	6.41 ± 0.01

* Note: Values represent the mean ± SE; $n = 3$.

The antioxidant scavenging activity of BRP was 56.15%. Sompong et al. [35] analyzed different black rice varieties for bioactive compounds and antioxidant activity and found that the anthocyanin content ranged between 109.52 and 256.61 mg of cyaniding 3-glucoside/100 g, the total phenolic compounds ranged between 336.69 and 665.16 mg as GAE/100 g, and the total antioxidant activity ranged between 59.9 and 83.9%. All the bioactive compounds and antioxidant activity of BRP presented in Table 1 were found to conform to the findings of a previous study [37].

The antioxidant activity of food is mainly conjugated to the concentration and the hydroxylation degree of the phenolic compound. Color reading characteristics showed that BRP has a purple color, making it a valuable technological ingredient in different dairy-food applications.

3.2. Physicochemical Properties of the Synbiotic Ice Cream

3.2.1. Chemical Properties

As seen in Table 3, total solids (TSs) are important in determining the quality of ice cream. The incorporation of BRP into ice cream formulations caused significant ($p < 0.05$) increases in the TS content as the level of BRP was raised. Because of the composition and the added amounts of BRP in the ice cream samples, these results were predictable. Thus, ice cream with a high TS content has a desirable body texture. Our results are consistent with Murtaza et al. (2004) [38] for fig-paste ice cream. Insignificant differences in fat and protein content at the higher concentrations of BRP were observed (Table 3). On the other hand, the addition of the BRP significantly enhanced the ash and carbohydrate contents ($p < 0.05$). These results are in agreement with Abd Rabo and Dewidar (2017) [39].

Table 3. Effect of addition of BRP on the main chemical composition (%), physicochemical, and rheological properties of ice cream samples made from camel milk.

Chemical Properties	Total Solids	Protein	Fat	Carbohydrates	Ash
Control	34.65 ± 0.34 [b]	3.51 ± 0.50 [a]	8.70 ± 0.11 [a]	16.15 ± 0.20 [c]	0.74 ± 0.00 [c]
T1	36.55 ± 0.60 [a]	3.50 ± 0.10 [a]	8.75 ± 0.07 [a]	17.18 ± 0.15 [b]	0.82 ± 0.00 [b]
T2	37.16 ± 0.33 [a]	3.25 ± 0.08 [a]	8.80 ± 0.10 [a]	17.90 ± 0.05 [a]	0.89 ± 0.00 [a]
T3	37.40 ± 0.35 [a]	3.10 ± 0.10 [a]	8.80 ± 0.15 [a]	18.20 ± 0.05 [a]	0.98 ± 0.00 [a]
			Physicochemical and Rheological Properties		
Ice cream treatments	**Freezing point (°C)**	**Overrun%**	**Viscosity (cP)**	**First drip time (min)**	**Complete melting times (min)**
Control	−2.34 ± 0.01 [d]	38.55 ± 0.27 [c]	324 ± 2.00 [d]	4.15 ± 0.00 [d]	43.45 ± 0.28 [d]
T1	−2.42 ± 0.00 [c]	39.88 ± 0.01 [b]	392 ± 2.51 [c]	5.70 ± 0.02 [c]	47.16 ± 0.14 [c]
T2	−2.47 ± 0.02 [b]	41.90 ± 0.10 [a]	421 ± 1.15 [b]	5.80 ± 0.00 [b]	49.76 ± 0.57 [b]
T3	−2.51 ± 0.00 [a]	41.80 ± 0.40 [a]	440 ± 1.79 [a]	6.10 ± 0.00 [a]	53.20 ± 0.20 [a]

Control: ice cream made without any replacements. T1: ice cream made by replacing 25% of skim milk powder with BRP. T2: 50% replacements of skim milk powder with BRP. T3: 75% replacements of skim milk powder with BRP. Values represent the mean ± SE; $n = 3$. Values represent the mean ± SE; $n = 3$. Averages with different superscripts differed significantly ($p \leq 0.05$); [abcd] letters within the same column with different superscripts differed significantly ($p \leq 0.05$).

3.2.2. Physical Properties of the Synbiotic Ice Cream

The quality of ice cream depends on several factors, such as the milk type used in the preparation of the mix, as it plays a critical role in the properties of the product, and the physical characteristics of the ice cream mixture produced by different processing methods that could alter its texture and appearance.

Furthermore, Table 3 shows the physical and rheological properties of ice cream produced from camel milk enriched with BRP. Significant differences were noticed between the treatments. The amount of BRP influenced the freezing point of the resultant ice creams. Hence, the freezing point is one of the factors influencing the quality of ice cream. If the mixture has a low freezing point, less water will be frozen when the ice cream exits the freezer. Thus, the ice cream's shelf life will be reduced, because it will be more susceptible to increasing the size of ice crystals when fluctuations in temperature occur. The lower freezing point may be due to the increase in serum phase concentration or to the decrease in solute molecular weight.

The overrun of ice cream is directly related to the yield and profit for the producer. The amount of BRP used in the ice cream samples had a significant impact on the overrun.

These results are in contrast with Abd Rabo and Dewidar (2017) [39] for ice cream produced from broken rice. Similar outcomes were concurred with by Darwish et al. (2016) [24], who incorporated Jerusalem artichoke tuber powder (JAT) into frozen yoghurt and noticed an increase in the liquefying obstruction, overwhelm, and thickness of dessert. It stands to reason that the advancement of dessert with JAT up to 20% will give buyers medical advantages and could be associated with business sectors such as functional ice cream. Viscosity is considered an important aspect for appropriate whipping and the retention of air cells. The viscosity of experimental mixes progressively increased with increasing the proportion of BR ice cream blends. The viscosity ranged from 3242.00 to 4401.97 cP (Table 3). In this respect, polysaccharides, such as starch, have been reported to increase the viscosity [7,39,40]. The lowest viscosity was recorded in the absence of BRP (control), causing the ice cream's texture to become diluted or form free-flowing liquid. These findings were similar to the results obtained by Ibrahim et al. (2021) [41], who manufactured synbiotic ice cream by incorporating okara. The time for first dripping and complete melting increased by increasing the level of BRP in the ice cream (Table 3). The effect of the addition of BRP at the different levels gave the longest melting time compared with the control. These results show the high resistance of ice cream fortified with BRP against melting. This may be due to the high content of total solids in BRP. Similar trends were observed in previous studies [24,26]. The higher viscosity of the experimental mixes might be partly responsible for the low melting rate of the treatments. The obtained results are in parallel with those of El-Samahy et al. (2015) [25].

Color is an important factor in determining the quality of food products, possibly due to its relationship with desirability and food safety. The color parameters of synbiotic ice cream are presented in Figure 1. Significant differences in the color parameters between synbiotic ice creams and the control samples were observed. The levels of BRP added significantly influenced the lightness (L*), a*, and b* of ice cream ($p < 0.05$). The color of the ice cream samples was a purplish pink, as a result of the different levels of BRP used in the formulations. The BRP addition of 75% (T3) showed the highest lightness (86.7) and a* (redness) (6.80), whilst its b* (yellowness) (13.3) was comparable to control and other samples.

3.2.3. The Acidity and pH Levels of Synbiotic Ice Cream Samples

The titratable acidity values tended to slightly decrease, and the pH values increased with increasing the proportion of BRP in the blend. The pH ranged from 5.32 to 5.77, and the results were statistically different ($p < 0.05$) after 60 days of storage at −18 °C. The acidity of the examined samples was in the range of 0.19–0.39 (Figure 2). The obtained results are similar to those obtained by Sabet-Sarvestani et al. (2021) [40] for synbiotic ice cream. The pH value of the control treatment was found to be 5.77 and decreased to 5.72 after 75% replacement of skim milk powder with BRP in the ice cream mix (zero time).

The pH and acidity values (as lactic acid) of freshly prepared ice creams were affected by the level of BRP (Figure 2). However, during storage, the pH of all investigated samples decreased and the acidity increased ($p < 0.05$). The increase in acidity and pH for the synbiotic ice creams could be attributed to the fermentation of lactose into lactic acid by the action of lactic acid bacteria. These results are in agreement with Abd Rabo and Dewidar [39], who found that titratable acidity values tended to slightly decrease and the pH values increased with increasing the proportion of broken rice milk in the blend of functional ice cream. Moreover, similar results in the acidity and pH values were found in previous studies by Sayar et al. (2022) [6], who found that the acidity values of the ice cream samples increased depending on the blueberry amount, while the pH values decreased.

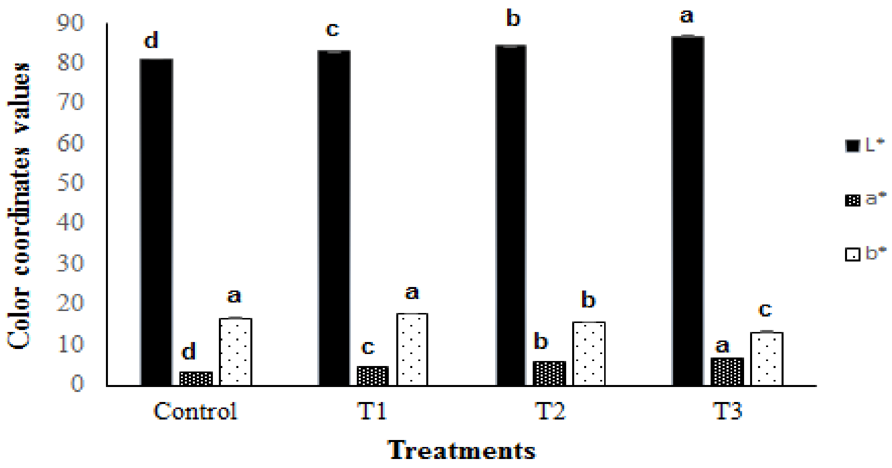

Figure 1. Color coordinates of ice cream samples made from camel milk formulated with BRB. Control: ice cream made without BRP. T1: ice cream made by replacing 25% of skim milk powder with BRP. T2: 50% replacements of skim milk powder with BRP. T3: 75% replacements of skim milk powder with BRP. Measurements were recorded as L* to express (lightness), +a* (redness) and +b* (yellowness) based on CIE (Commission Internationale de I'Eclairage) color coordinates. Values represent the mean ± SE; n = 3. Means with different small $^{(a–d)}$ superscripts are significantly different between the treatments ($p \leq 0.05$).

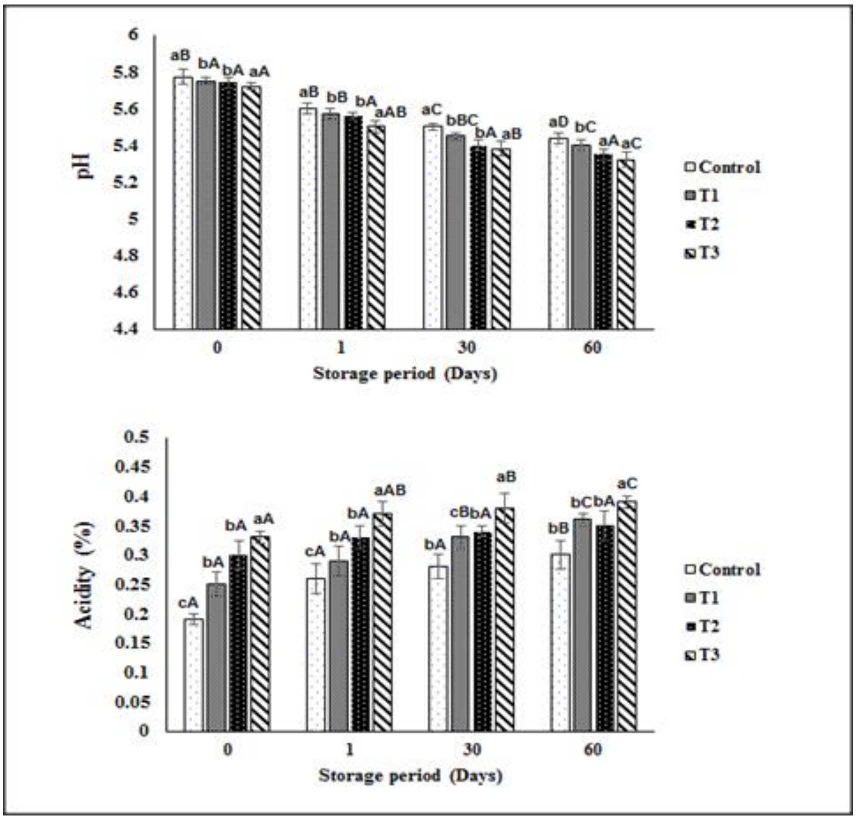

Figure 2. The pH and acidity values ice cream samples during storage periods at freezing temperature. Control: ice cream made without any replacements. T1: ice cream made by replacing 25% of skim milk powder with BRP. T2: 50% replacements of skim milk powder with BRP. T3: 75% replacements of skim milk powder with BRP. Values represent the mean ± SE; n = 3 Means with various small (a–c) letter superscripts for the effect of storage time and capital (A–D) letter superscripts for the effect of different levels of BRP ($p \leq 0.05$).

3.2.4. Microbiological Properties of Synbiotic Ice Cream (Survival of Probiotic Bacteria)

To investigate the effect of BR on the culture viability of synbiotic camel-milk ice cream, the samples were followed throughout storage at −18 °C for 60 days for total bacterial count and viability of *L. acidophilus* LA-5 (Table 3). It is clear that the pH and acidity values of the ice cream samples supported the survival rate of probiotic bacteria during the first 30 days of storage (Table 4). The total bacterial count was slightly affected during storage and ranged between 7.35 and 8.67 log cfu/g in the samples. These results were consistent with Sabet-Sarvestani et al. (2021) [40]. The highest counts were noticed for the ice cream mix, especially for the T3 sample (75% replacement of skim milk powder with BRP). Total bacterial counts of all samples were significantly decreased ($p < 0.05$) at the end of storage (60 days) in comparison to the beginning. The decrease in bacterial cell counts may be attributed to the pH reduction and the freezing shock, which damaged the bacterial cell wall and then killed the cells [42]. Similarly, the count of *L. acidophilus* LA-5 was slightly affected during storage for the first 30 days. Similarly, the viable count of both probiotic bacteria was significantly decreased ($p < 0.05$) in all ice cream samples at the end of storage in comparison to the beginning. Furthermore, the viable count of *L. acidophilus* LA-5 ranges between 7.25 and 8.50 log cfu/g throughout the storage up to 60 days, exceeding the limit of 7 log cfu/g, which is required to obtain a therapeutic (anti-diarrheal) effect [43–45]. Therefore, the probiotic bacteria revealed an excellent survival rate during the storage period (at least 30 days), thus ensuring the therapeutic effect of synbiotic camel-milk ice cream.

Table 4. Viability of *L. acidophilus* LA-5 in ice cream during storage periods at freezing temperature (log cfu/g).

Storage Periods (Days)	Treatments			
	Control	T1	T2	T3
	Total Bacteria Count (log cfu/g)			
Ice cream Mix	8.35 ± 0.10^{aC}	8.41 ± 0.09^{aB}	8.41 ± 0.10^{aB}	8.66 ± 0.06^{aA}
1	8.21 ± 0.09^{bC}	8.23 ± 0.09^{bC}	8.40 ± 0.09^{abB}	8.50 ± 0.16^{bA}
30	8.05 ± 0.18^{cD}	8.08 ± 0.20^{cC}	8.19 ± 0.12^{bB}	8.30 ± 0.09^{cA}
60	7.35 ± 0.16^{dC}	7.70 ± 0.21^{dB}	8.00 ± 0.13^{cA}	8.00 ± 0.13^{dA}
	***Lactobacillus acidophilus* LA-5 (log cfu/g)**			
Ice cream Mix	8.20 ± 0.06^{aB}	8.23 ± 0.11^{aB}	8.40 ± 0.05^{aAB}	8.50 ± 0.08^{aA}
1	8.10 ± 0.17^{bC}	8.17 ± 0.14^{bB}	8.11 ± 0.12^{bC}	8.31 ± 0.08^{bA}
30	8.00 ± 0.10^{bcC}	8.06 ± 0.15^{cB}	8.13 ± 0.13^{bA}	8.13 ± 0.09^{cA}
60	7.25 ± 0.13^{cC}	7.44 ± 0.11^{cdB}	7.62 ± 0.11^{cA}	7.66 ± 0.07^{dA}

Control: ice cream made without any replacements. T1: ice cream made by replacing 25% of skim milk powder with BRP. T2: 50% replacements of skim milk powder with BRP. T3: 75% replacements of skim milk powder with BRP. Values represent the mean ± SE; $n = 3$. ^{ABCD} Letters within the same row with different superscripts differed significantly ($p \leq 0.05$); ^{abcd} letters within the same column with different superscripts differed significantly ($p \leq 0.05$).

The highest count for *L. acidophilus* LA-5 throughout the storage was obtained for the T3 sample (75% replacement of skim milk powder with BRP). Furthermore, *L. acidophilus* LA-5 survived in ice cream samples for over 60 days of storage. Our results are consistent with those of Aklin et al. (2008) [46] for probiotic ice cream produced by using different dietary fibers. The obtained results also indicated that BRP has a substantial protective effect on the viability of *L. acidophilus*. Charalampopoulos et al. (2002) [47] reported that wheat extract had a significant protective effect on the viability of *L. acidophilus* under acidic conditions, and do Espírito Santo et al. (2012) [48] declared that apple fiber has assisted the viability of *L. acidophilus* and *Bifidobacterium lactis* in yoghurt. Góral et al. (2018) [49] examined probiotic ice cream and found that the count of bacterial cells was in the range of 9–11 log cfu/g. On the other hand, in a study by Akalin and Erisir (2018) [33], a decrease in the bacterial count in the all samples from 0.9 to 0.3 log cfu/g was noticed during storage when producing ice cream as follows: C = control probiotic ice cream, T1 = probiotic ice cream with 2% apple fiber, T2 = probiotic ice cream with 2% orange fiber, T3 = probiotic ice cream with 2% oat fiber, T4 = probiotic ice cream with 2% bamboo fiber, and T5 = probiotic ice cream with 2% wheat fiber.

3.2.5. Sensory Properties

The sensory characteristics given by the panelists are presented in Figure 3. The sensory properties, including flavor, texture, melting properties, and color-appearance, of camel-milk ice cream samples were evaluated. Regarding flavor, T3 had the lowest score compared to the control and the low concentration of BRP. This may be due to the distinct off-taste of black rice at higher concentrations [50]. Regarding the body texture and melting properties, T2 and T3 had the higher scores compared to the control and T1 samples. This can be attributed to the amount of BRP added to ice cream mixes and increasing the polysaccharides and total solids, which increased the viscosity and enhanced the body texture and melting properties of the resultant ice cream.

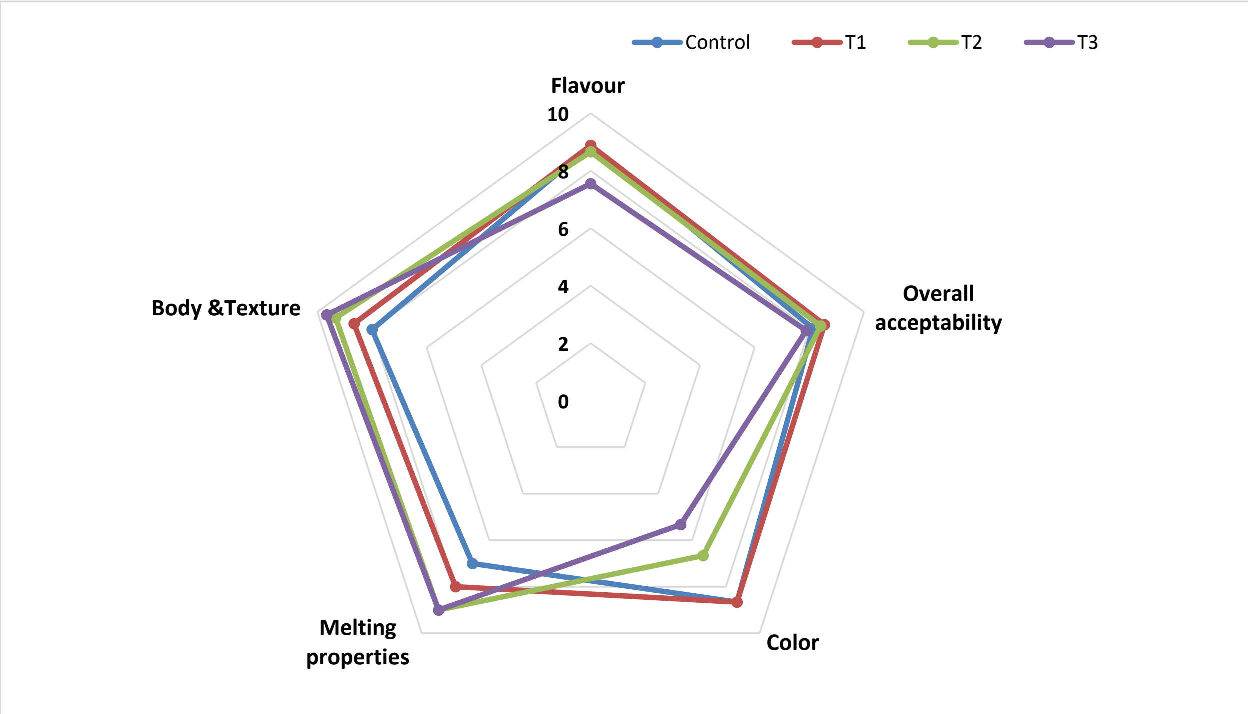

Figure 3. Sensory evaluations of ice cream samples. Control: ice cream made without any replacements. T1: ice cream made by replacing 25% of skim milk powder with BRP. T2: 50% replacements of skim milk powder with BRP. T3: 75% replacements of skim milk powder with BRP. Values represent the mean ± SE; n = 15.

Regarding the color scores, T1 had the same score as the control sample. In contrast, the T3 sample had the lowest scores for color properties, which can be attributed to the increased amount of BRP ($p < 0.05$). These results are consistent with those obtained for ice-cream color parameters (Figure 1). The L* (lightness) value increased with increasing the BRP in the ice cream mixes ($p < 0.05$). These results are consistent with Abd Rabo and Dewidar (2017) [39], who showed that the most acceptable treatments were those made by replacing 25 and 50% of skim milk with broken rice in ice cream samples. Therefore, the addition of black rice powder at 25 and 50% in ice cream produced from camel milk had the highest sensory score compared to control and T3 (75% BR) samples.

4. Conclusions

Given the above information, a synbiotic camel milk ice cream formulated with black rice powder (BRP) was produced. The incorporation of BRP enhanced the physicochemical and rheological properties of the ice cream samples. BRP has a significant protective effect on the viability of probiotic bacteria. The sensory characteristics of the resulting ice cream were also improved, with potential beneficial health effects, by formulating ice cream with 25-to-50% BRP. On an industrial scale, when using BRP for the production of synbiotic ice cream, it is critical to select the strain and ensure the survival of the probiotic bacteria throughout storage. Overall, using BR as a food ingredient may assist in increasing and improving people's health and well-being.

Author Contributions: W.F.E., A.H.A. and M.R.S., were involved in the conception of the research idea and methodology design, supervision, and data analysis and interpretation. M.H.A.-M., M.A.A., W.A. and E.K.E. were involved in methodology and drafting and preparing the manuscript for publication and revision. The funders had no role in data collection and analysis, the decision to publish, or the preparation of the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: Thanks and appreciation to the Saudi Ministry of Environment, Water, and Agriculture, facilitated by General Administration of Animal Productions for enabling research and using its facilities.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available upon request from the corresponding author.

Acknowledgments: The authors thank the Taif University Researchers supporting project number (TURSP-2020/93), Taif University, Taif, Saudi Arabia, for support.

Conflicts of Interest: The authors declare no conflict of interest.

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