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Development of Fermented Camel Milk Incorporating Oats and Sukkari Date Palm Fruit: Nutritional, Physicochemical, Functional, and Organoleptic Attributes

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Abstract: Camel milk-based products have shown significant interest and remarkable growth in recent years. These products are valued as functional items due to their unique nutritional properties and potential health benefits. This study prepared fermented camel milk with the incorporation of unconventional ingredients, oat beverage and date palm fruit. Camel milk was mixed with 10% of Sukkari date paste with different concentrations of oat beverage (0, 25, 50, and 75%). The treatments were then fermented at 42 °C for roughly 3 h using ABT-5 starter culture. Multiple tests were then performed during the storage period to investigate the effects of oats supplementation on the characteristics of the prepared treatments. The results showed that the most favorable treatment was T2 (25% of oat beverage); it showed higher microbial activity by 2–7% compared to the control treatment, leading to a significant increase in total phenolic content and antioxidant activity. An increase in β-glucan content was also observed (0.05 g 100 g^{-1} DW), although more enhancements are suggested to reach at least 0.1 g 100 g^{-1} DW if considering β-glucan enrichment. Further, a significant increase in iron content was recorded in only T2 compared to other treatments; a decrease in phytic acid due to increased microbial activity in T2 is a possible explanation. Furthermore, T2 was the most liked treatment regarding taste, color, aroma, and texture. In conclusion, a 25% of oat beverage supplementation in fermented camel milk showed desirable effects and provided an innovative fermented camel milk. Investigating higher concentrations of more than 25% but less than 50% of oat beverages is suggested.

Keywords: camel milk; *Avena sativa*; *Phoenix dactylifera*; fermentation; nutrition; food supply

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1. Introduction

The production and development of camel milk-based products have shown great interest and huge growth for the last few years, particularly in Saudi Arabia, where camels represent domestic, cultural, and traditional significance and are considered highly prized livestock [1]. The estimated number of camels in Saudi Arabia reached nearly 1.6 million, with milk production exceeding 135,000 tonnes in 2021 [2]. Besides its economic value, camel milk has a high-quality nutritional profile rich in protein with a lower fat content than other livestock's milk, such as cow's. It also contains excellent amounts of vitamins and minerals such as ascorbic acid, which is 3–5 times higher than that in cows' milk. The iron content is also higher by 10 times compared to that in the latter [3–6]. In addition, camel milk contains higher concentrations of free amino acids and peptides compared to cow's milk, which could contribute to the successful production of fermented milk as peptides are easily metabolized by peptidase enzymes found in probiotics such as *Bifidobacterium* species [6,7].

Fermented food and beverages have also gained interest over the past decades. Fermentation products have been demonstrated to exert several health-beneficial effects. They are linked to the prevention and treatment of different diseases, such as obesity and

type 2 diabetes, cardiovascular diseases, upper respiratory infections, and certain cancers [8–11]. Fermentation can significantly enhance the foods' organoleptic properties and nutrient profile, leading to health-promoting effects. For this particular reason, the development and production of fermented food and beverages have shown notable advancements and innovations in the last few years; for instance, a study reported the use of sea buckthorn syrup for the supplementation of fermented soy-based beverage at a concentration of 20% as a substrate for *Lactobacillus paracasei* and *B. animalis*. This approach significantly improved the probiotics' growth and led to major enhancements in its antioxidant capacity [12]. In another study, honey was used at a concentration of 3% to supplement oat-based beverage, and results showed significant improvements in its probiotic activity with enhanced antioxidant capacity [13]. The supplementation of microalgae in fermented dairy products showed constant enhancements in their antioxidant capacity with desirable changes in their physicochemical properties; however, it showed significant negative effects on sensory characteristics [14]. Another study recommended the supplementation of inulin and white currant juice as excellent functional ingredients holding prebiotic properties in the development of fermented milk products [15]. In another recent study, the supplementation of 10–12.5% date palm fruit in fermented camel milk enhanced its functional properties, with maintained technological characteristics and probiotic growth activity. Compared to control samples, a more enhanced flavor was also observed [16]; camel milk is characterized by a slightly salty taste [6]. Thus, dates' sweetness can mask its salty taste. In this regard, date palm fruit can be an excellent choice in the development of functional products; regardless of its intense sweetness due to its high sugar content, dates have other high-quality nutrients, including dietary fibers, fatty acids, essential amino acids, minerals, and vitamins, as well as other bioactive substances with strong antioxidant potential. Antioxidants such as phenolic acids, polyphenols, and carotenoids were found in high amounts in different varieties of dates [17–20].

In this context, this study aims to produce innovative fermented camel milk supplemented with an oat beverage; incorporating oats as an innovative ingredient was due to its well-known functional properties. For instance, oat polysaccharides, mainly β-glucans, and its avenanthramides can provide an excellent functional product leading to several health-beneficial effects [21–23]. It is also well demonstrated that the consumption of oats has been linked to several health-promoting effects, such as anti-hypercholesterolemic and antidiabetic, as well as anti-inflammatory effects [22–25]. Further, a concentration of 10% date fruit paste was selected to achieve the desired level of sweetness, as previously recommended [16]. The produced fermented milk will potentially serve as a functional beverage suitable for various individuals of all ages, including children, adults, and athletes.

2. Materials and Methods

2.1. Materials, Ingredients, and Starter Culture

Camel milk was obtained from the College of Agriculture and Veterinary Medicine Farm, Qassim University, on 7 May 2023. Old-fashioned rolled oats were purchased from the local market of Buraydah, Saudi Arabia (manufactured by Hanna, Federal Oats Mills, 13400, Butterworth, Malaysia). Date palm paste, of the Sukkari variety yield of season 2022, was purchased from Aloos For Dates (Buraydah, Qassim, Saudi Arabia). The chemical composition of camel milk, rolled oats, and date paste is shown in Table 1. ABT-5 starter culture, consisting of *Streptococcus thermophiles*, *L. acidophilus*, and *B. bifidum* (freeze-dried direct-to-vat set form (DVS), stored at –20 ± 1 °C) was obtained from Chr. Hansen, Copenhagen, Denmark.

2.2. Preparation of Oat Beverage

Oat beverage was prepared as follows: 80 g of old-fashioned rolled oats were mixed with 1 L of tap water and 0.35 g of food-grade α-amylase. The mixture was homogenized in a high-speed blender for about 1 min, liquefied at 65 ± 2 °C for 23 ± 2 min, and then heated

to 100 °C for 1 min to inactivate the enzyme. After cooling down to room temperature, the mixture was well-filtered in a mesh cloth to obtain a smooth oat beverage stored at 4 °C.

Table 1. Chemical composition of raw materials (mean ± SE, *n* = 6).

Constituents	Camel Milk ^	Rolled Oats *	Sukkari Date Paste *
Macronutrients (g 100 g^{-1})			
Protein	2.68 ± 0.09	10.5	2
Total carbohydrates		70.5	75
Dietary fibers	-	10.8	8
Sugars **	3.69 ± 0.45		66
Total Fat	2.78 ± 0.13	9.3	-
Minerals (mg 100 g^{-1})			
Calcium	105.09 ± 7.32	-	39
Magnesium	8.93 ± 0.68	113	43
Potassium	111.93 ± 3.09	ND	656
Sodium	51.38 ± 3.87	7	ND
Phosphorus	60.52 ± 3.92	ND	ND
Copper	0.17 ± 0.04	ND	0.3
Iron	0.63 ± 0.07	3.9	1
Manganese	ND	ND	0.3
Zinc	0.51 ± 0.04	2.4	ND

*: based on the manufacture data; **: determined as lactose in camel milk; ^: based on wet weight; ND: not determined.

2.3. Preparation of Fermented Camel Milk

The prepared oat beverage was mixed homogenously in a high-speed mixer with freshly pasteurized camel milk at concentrations of 0, 25, 50, 75, and 100% with the addition of 10% Sukkari paste to each, obtaining five different samples prepared in sterilized screw-cap bottles (Table 2; Figure 1). The samples were then heated in a water bath to 80 °C for 1 min for pasteurization. After cooling to 40 °C, ABT-5 starter culture at 0.1 g to 100 mL was added to each sample, shaken well, and incubated at 42 °C for roughly 3 h. The samples were then stored at 4 ± 1 °C for 21 days for further analysis.

Table 2. The percentage of oat beverage and date palm paste incorporated in fermented camel milk.

Treatments	Oat Beverage (%)	Dates Paste (Sukkari) (%)
T1	0	10
T2	25	10
T3	50	10
T4	75	10
T5	100	10

Abbreviations: T, treatment.

2.4. Determination of Chemical and Physicochemical Properties

All samples were subjected to the determination of moisture, ash, total solids, crude protein, fat, fiber, total carbohydrates, pH, and titratable acidity according to the AOAC standard methods [26].

2.5. Estimation of Microbial Growth

The viable count of *Str. thermophiles*, *L. acidophilus*, and *B. bifidum* in the fermented samples were estimated according to the standard plate count method of Vinderola and Reinheimer [27]. Briefly, each sample was suspended in sterile peptone water at the ratio of 1:9 to prepare a series of dilutions; 1 mL of appropriate dilutions were then inoculated in sterile Petri plates, and a duplicate of selective mediums for each bacterial strain was poured using the standard pour plate method. The selective mediums were as follows: M17 agar (Millipore, Sigma, Ronkonkoma, NY, USA) was used for incubating *Str. thermophiles*

aerobically at 37 °C for 48 h, MRS agar (Neogen, Lansing, MI, USA) was used for *L. acidophilus* incubating anaerobically at 37 °C for 72 h, and Lithium Propionate MRS (LP-MRS) media was used for incubating *B. bifidum* anaerobically at 37 °C for 72 h [27]. The anaerobic incubation was performed using the GasPak system (GasPak System-Oxoid, Basingstoke, Hampshire, UK). Results of the viable count were expressed as logarithm colony-forming units per mL (log10 CFU mL^{-1}) of the sample.

Figure 1. Treatments of fermented camel milk incorporated with oats and date palm fruit (**A**–**E**): treatments 1 to 5; see Table 2 (Section 2.3) for the detailed treatments.

2.6. Determination of β-Glucan Content

The β-glucan content in the fermented samples was determined using a mixed linkage (1–3, 1–4) β-glucan assay kit by Megazyme International (Wicklow, Ireland) following the manufacturer protocol for liquid samples (method C). Briefly, the liquid samples were extracted repeatedly using aqueous ethanol to remove free sugars and fats. Samples were then incubated with lichenase at 50 °C for 1 h, hydrolyzed with β-glucosidase at 50 °C for a further 10 min, and then incubated with glucose determination reagent at 50 °C for 20 min, generating a pinkish–reddish color (Figure S1). The absorbance of the generated color was measured at 510 nm, and the final β-glucan content was expressed as g 100 mL^{-1} sample.

2.7. Determination of Total Phenolic Content and Antioxidant Capacity

The fermented samples' total phenolic content (TPC) was determined using the Folin–Ciocalteu method [28]. In brief, 50 µL of methanolic extract was mixed with 100 µL Folin–Ciocalteu reagent for 5 min. Then, 100 µL of 7.5% sodium carbonate solution (*w*/*v*) was added. The extracts were then incubated in the darkness for 60 min (300 rpm, room temperature). The absorbance was then measured at 765 nm using a microplate reader (BioTek, Winooski, VT, USA). A standard curve of gallic acid (GA) solution (R^2 = 0.99) was used to compare measurements, and results were expressed as milligrams of gallic acid equivalents (GAE) per 100 g (mg of GAE g^{-1} DW).

The antioxidant capacity was measured in the methanolic extracts using DPPH radicals, according to Yawadio Nsimba et al. [28]. In brief, 50 µL of the extract was added to 200 µL of the DPPH solution. After incubating in the darkness for 60 min at room temperature, the absorbance was measured at 517 nm using a microplate reader (BioTek, Winooski, VT, USA). Trolox solution was used for preparing a standard curve, and the antioxidant capacity was expressed as micromoles of Trolox Equivalents (TE) per gram (µmol TE g^{-1}). Further, ABTS radical was also used to test the extracts' radical scavenging activity according to the adapted method of Lu et al. [29].

2.8. Instrumental Color Measurements

The samples' colors were measured using a ColorFlex colorimeter (ColorFlex, Reston, AV, USA); data were noted in triplicates in terms of L* for lightness (ranging from 0 to 100, black to white), a* for redness (ranging from +60 to −60, red to green), and b* for yellowness (ranging from +60 to −60, yellow to blue) according to the International Commission for Color Measurement (CIE) system. Further, the hue angle (H°), chroma value (C*), color changes (ΔE), and browning index (BI) were calculated following the formulas [30]:

$$C^* = \left(a^2 + b^2\right)^{0.5} \quad (1)$$

$$H^\circ = \tan^{-1}\left(\frac{b}{a}\right) \quad (2)$$

$$BI = \frac{\left[100\left(\frac{a+1.75L}{5.645L+a-3.012b}\right) - 0.31\right]}{0.17} \quad (3)$$

$$\Delta E = \left[(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2\right]^{0.5} \quad (4)$$

The H° is a qualitative attribute of color applied to describe whether an object is red, orange, yellow, green, blue, or violet, while the C* is a quantitative attribute that describes the intensity of color changes [31].

2.9. Sensory Analysis

The sensory attributes, including taste, color, texture, aroma, aftertaste, and overall acceptability, were tested by ten panelists from the Food Science and Human Nutrition Department, Agriculture and Veterinary Medicine College, Qassim University. The standard 9-hedonic scale was applied to test each attribute; the smallest score '1' represents "most dislike", while the highest '9' represents "most like". Four testing routes were performed for storage periods of 1, 7, 14, and 21 days, and water was offered for rinsing the mouth between testing samples.

2.10. Statistical Analysis

The statistical analysis was performed using the SPSS software package (version 22.0 for Windows). One-way ANOVA was used, followed by a post hoc test, and p-values < 0.05 were considered statistically significant, according to Steel et al. [32].

3. Results

3.1. Chemical Composition

The chemical compositions of the five treatments (T1–T5) showed gradual changes with the gradual change in the ratios of camel milk to oat beverage; as shown in Table 3, the moisture content showed a significant increase from 86.73 ± 0.08% in T1 (100% camel milk) to 90.77 ± 0.03% in T5 (100% oat beverage). Accordingly, the total solids and ash content significantly showed a gradual decrease from T1 to T5 (13.27 ± 0.08 to 9.23 ± 0.03% and 0.90 ± 0.04 to 0.26 ± 0.01% of total solids and ash, respectively). The different treatment ratios also showed significant changes in the major chemical components; with decreased camel milk ratios, crude protein and fat content decreased from T1 to T5 by 68 and 89%, respectively. However, replacing camel milk with 25 and 50% of oat beverage (T2 and T3) maintained sufficient amounts of protein and fats (3.3–2.6% and 2.6–1.8%, respectively); in other words, T2–T3 showed a decrease in protein and fat content by 14–33% and 24–46.5%, respectively. In contrast, increased oat beverage ratios showed a significant increase in available carbohydrates from T1 to T5 by 32.5%. Accordingly, the fiber content ranged from 0.67–1.61%, which significantly increased with increasing the portion of oat beverage in parallel with decreasing camel milk portion (Table 3).

Table 3. Chemical composition of fermented camel milk incorporated with oats and date palm fruit (based on wet weight) (mean ± SE, n = 3).

Parameter (%)	Treatments				
	T1	T2	T3	T4	T5
Moisture	86.73 ± 0.08 ^{e}	88.15 ± 0.02 ^{d}	88.79 ± 0.03 ^{c}	89.51 ± 0.01 ^{b}	90.77 ± 0.03 ^{a}
Total Solids	13.27 ± 0.08 ^{a}	11.85 ± 0.02 ^{b}	11.21 ± 0.03 ^{c}	10.49 ± 0.01 ^{d}	9.23 ± 0.03 ^{e}
Ash	0.90 ± 0.04 ^{a}	0.68 ± 0.02 ^{b}	0.54 ± 0.01 ^{c}	0.42 ± 0.01 ^{d}	0.26 ± 0.01 ^{e}
Crude Protein	3.86 ± 0.06 ^{a}	3.31 ± 0.09 ^{b}	2.59 ± 0.18 ^{c}	1.99 ± 0.06 ^{d}	1.23 ± 0.09 ^{e}
Fat	3.50 ± 0.06 ^{a}	2.63 ± 0.03 ^{b}	1.87 ± 0.03 ^{c}	0.87 ± 0.03 ^{d}	0.38 ± 0.02 ^{e}
Available Carbohydrates	4.34 ± 0.19 ^{c}	4.36 ± 0.10 ^{c}	5.16 ± 0.21 ^{b}	5.96 ± 0.13 ^{a}	5.75 ± 0.17 ^{a}
Dietary Fiber	0.67 ± 0.06 ^{c}	0.87 ± 0.09 ^{d}	1.05 ± 0.04 ^{c}	1.25 ± 0.11 ^{b}	1.61 ± 0.11 ^{a}

Abbreviations: T, treatment; see material and methods (Table 2). Different superscripted letters (a–e) between any two means within the same row indicate significant differences at $p < 0.05$.

3.2. Mineral Contents

Mineral contents, including macro- and micro-elements, were determined in the different treatments (T1–T5), as shown in Table 4. Most determined elements showed a significant gradual decrease with increased oat beverage ratios to camel milk, including calcium, magnesium, potassium, sodium, phosphorus, copper, and zinc. The control camel milk (T1) contained the highest amounts of calcium (378.46 ± 0.97 mg kg^{-1}); replacement with 25 and 50% of oat beverage (T2 and T3) maintained sufficient amounts of calcium content (339.24 ± 7.08 and 257.45 ± 3.10 mg kg^{-1}, respectively), while T4 and T5 (75 and 100% of oat beverage) showed the highest decrease in calcium content, reaching 180.71 ± 0.84 and 57.38 ± 2.07 mg kg^{-1}, respectively. The latter two treatments also showed the highest decreases in other elements by 40 to 80%, while T2 and T3 showed decreases ranging from 9 to 46%. Magnesium, potassium, sodium, phosphorus, copper, and zinc decreased T2 and T3 by 9 and 22%, 14 and 28%, 11 and 61%, 6 and 29%, 30 and 38%, and 17 and 46%, respectively. Clearly, the replacement with 50% oat beverage (T3) resulted in more reduction in the mineral content compared to T2.

Table 4. Mineral content (mg kg^{-1}) of fermented camel milk incorporated with oats and date palm fruit (based on wet weight) (mean ± SE, n = 3).

Elements		Treatments				
		T1	T2	T3	T4	T5
Micro-elements	Ca	378.46 ± 0.97 ^{a}	339.24 ± 7.08 ^{b}	257.45 ± 3.10 ^{c}	180.710.84 ^{d}	57.38 ± 2.07 ^{e}
	Mg	136.27 ± 0.76 ^{a}	124.24 ± 1.25 ^{b}	106.39 ± 2.80 ^{c}	102.13 ± 0.44 ^{c}	79.25 ± 0.73 ^{d}
	K	288.1 ± 0.68 ^{a}	246.91 ± 3.28 ^{b}	206.97 ± 1.14 ^{c}	185.02 ± 3.22 ^{d}	113.28 ± 2.43 ^{e}
	Na	256.82 ± 3.37 ^{a}	228.13 ± 2.28 ^{b}	100.18 ± 1.08 ^{c}	84.46 ± 3.41 ^{d}	38.85 ± 0.28 ^{e}
	P	22.26 ± 0.93 ^{a}	20.94 ± 0.41 ^{a}	15.85 ± 0.57 ^{b}	8.76 ± 0.51 ^{c}	5.83 ± 0.56 ^{d}
Micro-elements	Cu	0.49 ± 0.12 ^{a}	0.34 ± 0.11 ^{a}	0.28 ± 0.07 ^{a}	0.25 ± 0.08 ^{a}	0.23 ± 0.04 ^{a}
	Fe	3.68 ± 0.01 ^{a}	4.80 ± 0.28 ^{a}	4.40 ± 0.33 ^{a}	4.16 ± 0.43 ^{a}	3.85 ± 0.04 ^{a}
	Mn	0.57 ± 0.07 ^{b}	0.51 ± 0.04 ^{b}	0.55 ± 0.04 ^{b}	0.72 ± 0.01 ^{a}	0.74 ± 0.03 ^{a}
	Zn	2.09 ± 0.12 ^{a}	1.73 ± 0.02 ^{b}	1.12 ± 0.06 ^{c}	0.86 ± 0.16 ^{cd}	0.68 ± 0.15 ^{d}

Abbreviations: T, treatment; see material and methods (Table 2). Different superscripted letters (a–e) between any two means within the same row indicate significant differences at $p < 0.05$.

In contrast, the iron content showed a trend of increase with the increased oat beverage ratios by 13–30% (Table 4). Interestingly, the highest increase in iron content was observed in T2 (25% of oat beverage); other treatments containing 50–100% of oat beverage (T3–T5) showed an increase in iron content compared to T1 but were less than that recorded in T2. The manganese content also showed a significant increase of 26–30% but was only observed with higher ratios of oat beverage (T4 and T5). The other two treatments, T2 and T3, recorded declines in manganese content compared to T1 by 3.5 and 10.5%, respectively.

3.3. Microbial Growth, pH, and Acidity during Storage Time

The viable count of *Str. thermophiles*, *L. acidophilus*, and *B. bifidum* were determined during the storage period, as shown in Table 5. From the first day of storage up to day 14, most treatments showed an increase in microbial activity, but after 21 days of storage, it showed a significant decline. Interestingly, there were some significant differences between the different treatments (T1–T5) during storage periods; the replacement of camel milk with 25% oat beverage (T2) showed significantly higher microbial activity compared to T1 (100% camel milk) (7.46–8.39 vs. 7.30–7.98 $\log_{10}$ CFU mL^{-1} of *Str. thermophiles* in T2 vs. T1, respectively); *L. acidophilus* showed a consistent increase in T2 compared to T1 (6.00–6.64 vs. 5.59–6.05 $\log_{10}$ CFU mL^{-1} in T2 vs. T1, respectively). However, for *B. bifidum*, there were no significant differences between the two treatments (7.34–7.88 vs. 7.28–7.85 $\log_{10}$ CFU mL^{-1} in T2 vs. T1, respectively). The microbial activity for the other treatments (T3–T5) showed less viability decreases with increased ratios of oat beverage; the lowest microbial activity was observed in T5, which had less activity by 19–41% compared to T1 and T2.

Table 5. Changes in microbial growth ($\log_{10}$ CFU mL^{-1}) during the storage period of fermented camel milk incorporated with oats and date palm fruit (mean ± SE, n = 3).

Bacterial Strain	Storage Period (Days)	Treatments				
		T1	T2	T3	T4	T5
Str. thermophiles	1	7.30 ± 0.17^{cBC}	7.46 ± 0.18^{cA}	7.32 ± 0.17^{cB}	7.19 ± 0.13^{dC}	5.89 ± 0.04^{abD}
	7	7.91 ± 0.02^{aB}	8.39 ± 0.01^{aA}	7.74 ± 0.01^{bC}	7.36 ± 0.06^{cD}	5.84 ± 0.08^{bE}
	14	7.98 ± 0.01^{aA}	8.02 ± 0.08^{bA}	7.91 ± 0.01^{aA}	7.69 ± 0.05^{aB}	6.00 ± 0.06^{aC}
	21	7.77 ± 0.06^{bB}	8.00 ± 0.07^{bA}	7.79 ± 0.02^{bB}	7.51 ± 0.04^{bC}	5.93 ± 0.06^{abD}
L. acidophilus	1	5.59 ± 0.09^{dC}	6.00 ± 0.08^{cA}	5.45 ± 0.06^{cB}	5.40 ± 0.05^{bB}	3.29 ± 0.07^{aD}
	7	5.81 ± 0.06^{cB}	6.64 ± 0.09^{aA}	5.70 ± 0.07^{abB}	5.75 ± 0.09^{aB}	3.23 ± 0.11^{aC}
	14	6.05 ± 0.25^{bB}	6.56 ± 0.07^{bA}	5.57 ± 0.09^{bC}	5.48 ± 0.06^{bC}	2.30 ± 0.10^{bD}
	21	5.74 ± 0.04^{aA}	6.37 ± 0.07^{bA}	5.73 ± 0.05^{aB}	5.36 ± 0.07^{bC}	2.18 ± 0.10^{bD}
B. bifidum	1	7.28 ± 0.16^{cA}	7.34 ± 0.03^{bB}	7.20 ± 0.18^{bA}	6.79 ± 0.18^{cB}	5.53 ± 0.16^{aC}
	7	7.59 ± 0.02^{abA}	7.88 ± 0.05^{aC}	7.31 ± 0.19^{abB}	6.99 ± 0.13^{bC}	5.56 ± 0.15^{aD}
	14	7.85 ± 0.01^{aA}	7.53 ± 0.06^{aD}	7.42 ± 0.20^{aB}	7.23 ± 0.13^{aC}	5.66 ± 0.08^{aE}
	21	7.75 ± 0.08^{bA}	7.30 ± 0.09^{abC}	7.21 ± 0.19^{abB}	7.01 ± 0.15^{bC}	5.57 ± 0.10^{aD}

Abbreviations: T, treatment; see material and methods (Table 2). Significant difference at $p < 0.05$ is indicated by different subscripted letters, (a–d) between any two means within the same column, and (A–E) between any two means within the same row.

On the other hand, the pH values were monitored during the fermentation and storage time as a critical parameter aligning microbial growth and acid production. As shown in Figure 2, after roughly 3 h of fermentation, the pH values significantly decreased from 6.22–6.76 to 4.48–5.20, indicating an active and successful fermentation; lower values were observed with higher ratios of oat beverage to camel milk. After one day of storage, the values increased to 4.62–5.25, with T2 and T3 showing less of an increase than other treatments (4.62 and 4.65, respectively). Following day 7 of storage, the values decreased in almost all treatments to 4.11–4.31. After day 21, no changes were observed.

Furthermore, titratable acidity was also monitored during the storage period as another critical parameter reflecting the presence of acids in fermented products, mainly calculated as lactic acid. Figure 3 shows that the least amounts of acid were produced in T5 based on the lower acidity observed (0.34–0.49%) compared to that observed in other treatments. The acidity, in general, increased with decreased ratios of oat beverage to camel milk. However, T2 showed a higher acidity than that observed in T1 (1.07–1.17% vs. 1.08–1.19%, respectively), while T3 and T4 had a lower acidity ranging from 0.68 to 0.93% and 0.57 to 0.74%, respectively. Figure 3 also shows that during the storage period up to day 7, all treatments had increased acidity levels due to microbial growth. However, acids decreased by 30–63% during the last week.

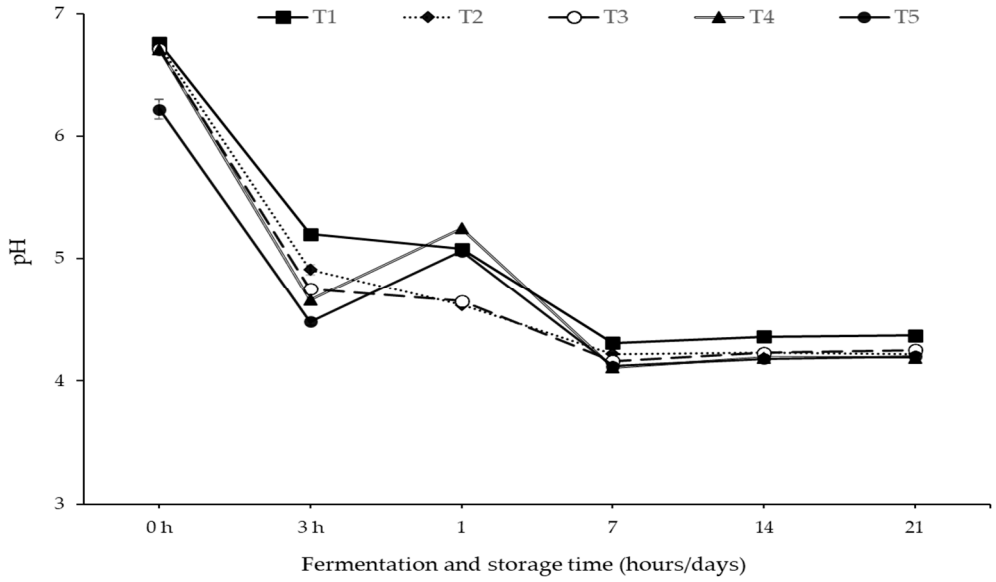

Figure 2. Changes in pH during fermentation and storage period (3 ± 1 °C, 21 days) of fermented camel milk incorporated with oats and date palm fruit. T1 to T5, consisting of camel milk incorporated with oat beverage at 0, 25, 50, 75, or 100%, respectively.

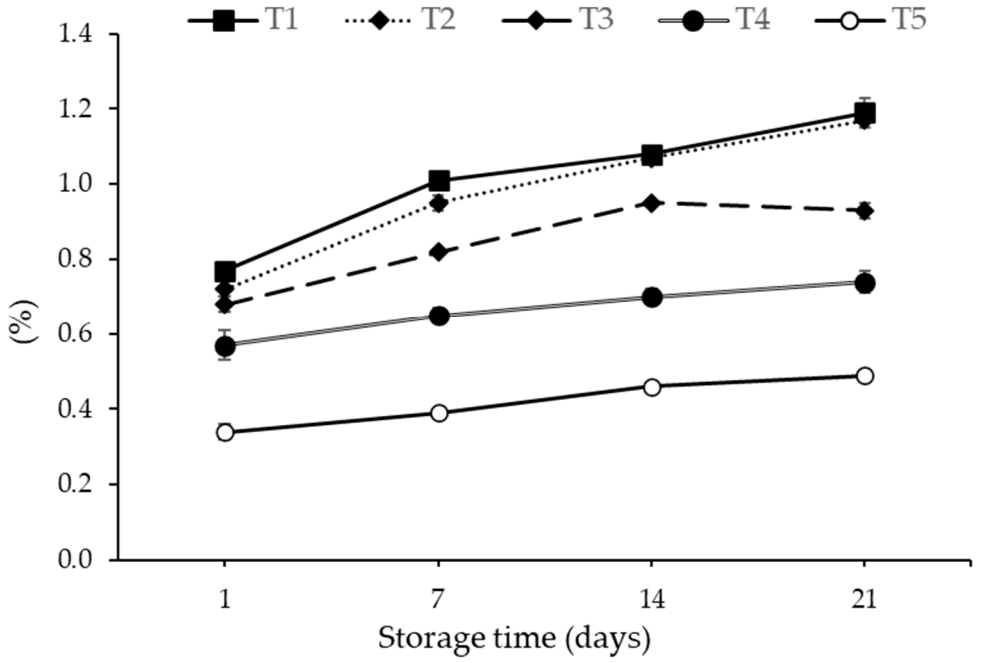

Figure 3. Changes in acidity during the storage period (3 ± 1 °C, 21 days) of fermented camel milk incorporated with oats and date palm fruit were calculated as lactic acid. T1 to T5, consisting of camel milk incorporated with oat beverage at 0, 25, 50, 75, or 100%, respectively.

3.4. β-Glucan Content

The changes in β-glucan content during the fermentation and storage time were determined in the current work. As shown in Figure 4, control camel milk (T1) had no detectable β-glucan; its replacement with oat beverage in different ratios resulted in a significant increase in a dose-dependent manner by 4–17 times. The gradual increase was visually noted in the generated color, from pale yellow in T1 to intense red in T5, as shown in Figure S1. The content increased from 0.00 g 100 mL^{-1} in T1 to 0.03, 0.09, 0.16, and 0.17 g 100 mL^{-1} in T2, T3, T4, and T5, respectively. However, during the storage period up to day 21, its content declined in a time-dependent manner. From the first day of storage up

to day 14, the β-glucan content decreased in T2–T5 by 33–66%, 11%, 12–19%, and 6–12%, respectively. At the end of the storage period, day 21, the content significantly declined to 0.00, 0.07, 0.11, and 0.15 in T2–T5, respectively.

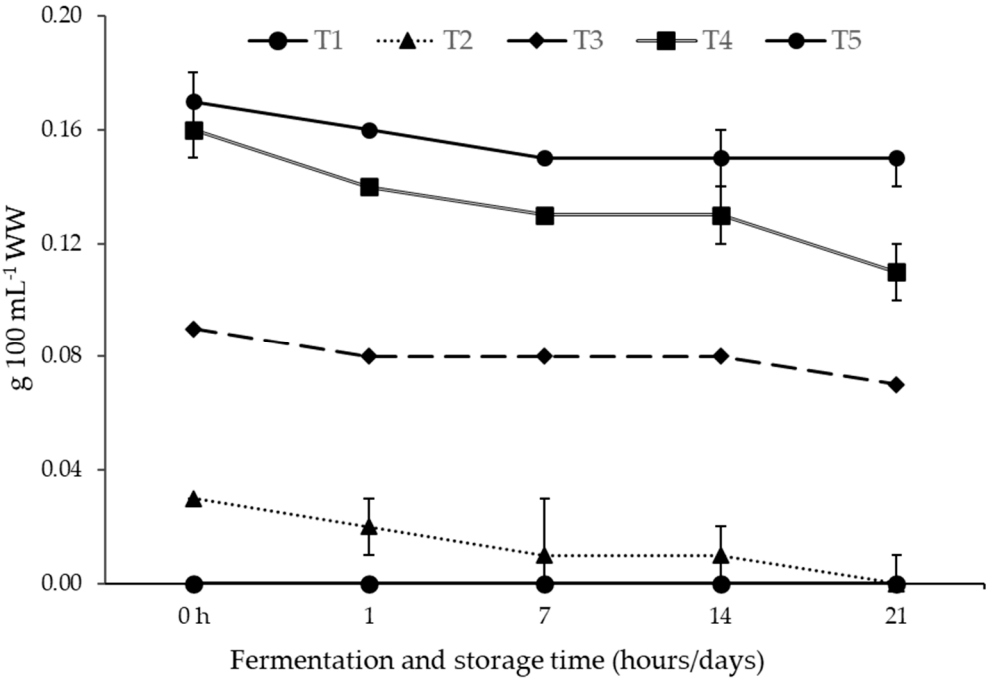

Figure 4. Changes in β-glucan content during fermentation and storage period (3 ± 1 °C, 21 days) of fermented camel milk. T, treatment. T1 to T5, consisting of camel milk incorporated with oat beverage at 0, 25, 50, 75, or 100%, respectively. Results expressed as g 100 mL^{-1} WW (wet weight) in means ± SE (n = 4).

3.5. Total Phenolic Content and Antioxidant Activity

The total phenolic content and the related antioxidant activity were measured during the storage time, as shown in Figures 5 and 6; results showed that with increased ratios of oat beverage to camel milk, the total phenolic content and antioxidant activity were significantly increased. The phenolic content increased from T1 to T5 by more than 200% (3.90 ± 0.08, 5.66 ± 0.42, 7.69 ± 0.06, 9.55 ± 0.41 and 12.14 ± 0.24 mg GAE g^{-1} DW observed after the first day of storage in T1–T5, respectively). The trend of higher phenolic content observed with higher ratios of oat beverage was consistent throughout the whole storage period. However, there were significant differences between treatments in the progress of releasing more phenolics during the different storage periods; after 7 days of storage, T1 and T2 showed an increase in the phenolic content by 21 and 10.6%, respectively. Other treatments, T3–T5, only increased after 14 days of storage. The first two treatments continued to increase up to 21 days of storage, reaching an increase of 30%, while the other treatments showed a decline at the end of the storage period.

Consistently, a higher antioxidant activity was observed with higher ratios of oat beverage to camel milk (41.66 ± 0.05, 65.53 ± 0.32, 84.88 ± 0.12, 97.99 ± 0.53 and 115.19 ± 0.07 μmol TE g^{-1} DW, observed after the first day of storage in T1–T5, respectively). Changes in antioxidant activity during the storage period showed some consistent results with those observed of the total phenolic content; after 7 days of storage, a higher antioxidant activity was observed in T2 and T3. After 21 days, the activity continued increasing in T1–T3, reaching 44.35 ± 0.03, 90.81 ± 0.040 and 105.01 ± 0.12, μmol TE g^{-1} DW, respectively. Other treatments (T4 and T5) showed less increase at the end of the storage period. In general, T1–T5 increased at the end of the storage period by 6.46, 38.58, 23.72, 31.74, and 29.81%, respectively, indicating that higher increases were noted in T2, followed by T4.

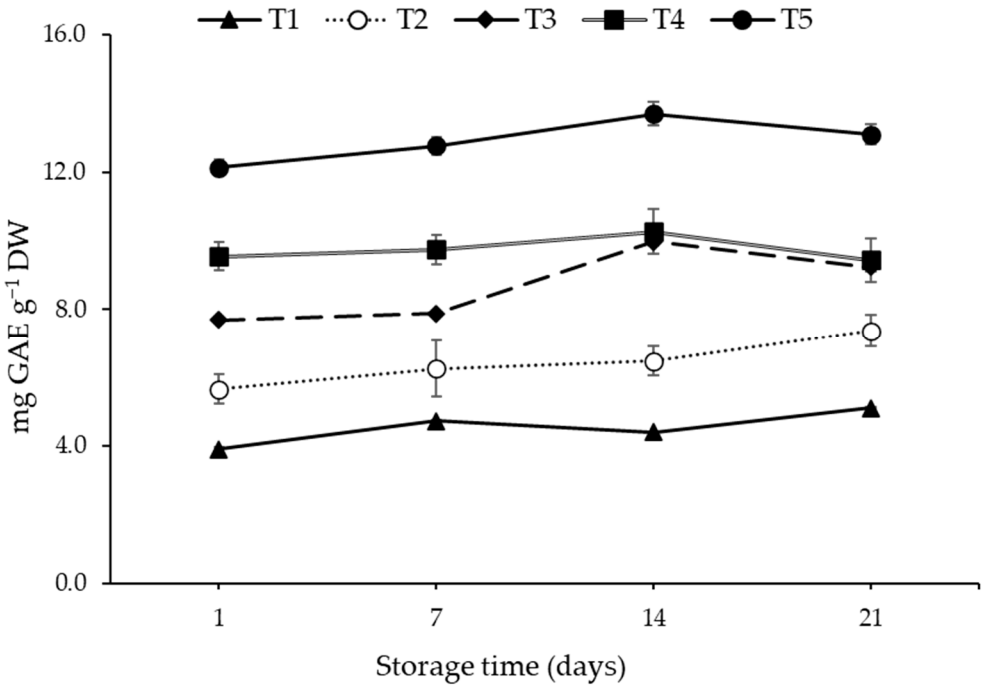

Figure 5. Changes in total phenolic content during storage periods (3 ± 1 °C, 21 days) of fermented camel milk incorporated with oats and date palm fruit. T, treatment. T1 to T5, consisting of camel milk incorporated with oat beverage at 0, 25, 50, 75, or 100%, respectively. Results expressed as mg GAE g-1 DW (dry weight) in mean ± SE (n = 3).

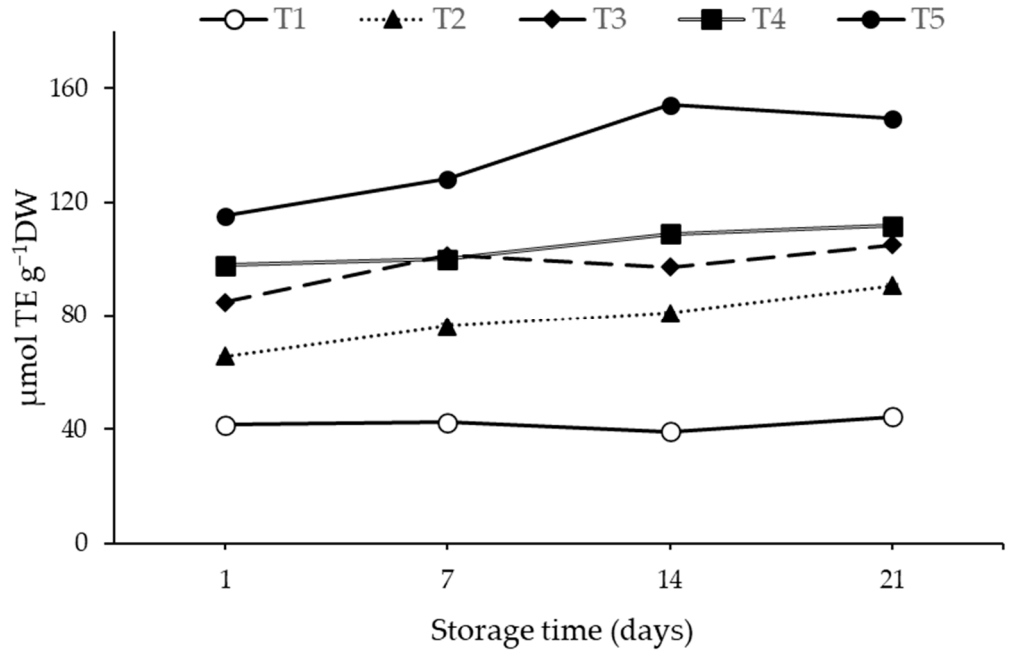

Figure 6. Changes in antioxidant activity during storage periods (3 ± 1 °C, 21 days) of fermented camel milk incorporated with oats and date palm fruit. T, treatment. T1 to T5, consisting of camel milk incorporated with oat beverage at 0, 25, 50, 75, or 100%, respectively. Results expressed as µmol TE g^{-1} DW (dry weight) in mean ± SE (n = 3).

3.6. Color Measurements

The changes in color parameters were measured in the different treatments, as shown in Table 6. There were significant changes in treatments' color with increased ratios of oat beverage to camel milk, based on the significant differences in ΔE, the color change

indicator. From T1 to T5, the treatments got darker based on the significant decrease in L*, the lightness indicator; in other words, treatments showed a decrease in color lightness in a dose-dependent manner by 3–27%. Figure 1 shows an apparent visual increase in the color darkness from T1 to T5, mostly distinct in T5. The browning index (BI) consistently shows a significant increase with increased ratios of oat beverage to camel milk. The color redness and yellowness, a* and b*, also increased in T1 to T5. These results shows that increased BI, a* and b* with decreased L*, explains the more darkness observed with higher ratios of oat beverage to camel milk. Further, the intensity of color changes, as indicated by the chroma value, C*, increased with higher ratios of oat beverage.

Table 6. Color parameters of fermented camel milk incorporated with oats and date palm fruit (mean ± SE, $n = 3$).

Parameter	Treatments				
	T1	**T2**	**T3**	**T4**	**T5**
L*	80.73 ± 0.11^{a}	78.47 ± 0.06^{b}	75.42 ± 0.21^{c}	69.52 ± 0.22^{d}	59.11 ± 0.33^{e}
a*	1.31 ± 0.12^{c}	1.76 ± 0.17^{bc}	1.96 ± 0.33^{bc}	2.34 ± 0.15^{b}	4.26 ± 0.21^{a}
b*	18.57 ± 0.07^{e}	19.29 ± 0.06^{d}	22.06 ± 0.06^{c}	25.73 ± 0.09^{b}	30.64 ± 0.26^{a}
C*	18.61 ± 0.07^{e}	19.37 ± 0.05^{d}	22.15 ± 0.05^{c}	25.84 ± 0.10^{b}	30.94 ± 0.29^{a}
b/a	14.44 ± 1.26^{a}	11.15 ± 1.12^{ab}	12.01 ± 2.25^{a}	11.09 ± 0.72^{ab}	7.23 ± 0.30^{b}
H°	86.02 ± 0.36^{a}	84.82 ± 0.51^{a}	84.97 ± 0.86^{a}	84.85 ± 0.32^{a}	82.14 ± 0.33^{b}
BI	26.76 ± 0.19^{d}	29.26 ± 0.08^{d}	35.75 ± 0.41^{c}	47.55 ± 0.53^{b}	75.60 ± 1.65^{a}
ΔE	0 ± 0^{e}	2.69 ± 0.07^{d}	6.65 ± 0.20^{c}	13.58 ± 0.24^{b}	25.19 ± 0.43^{a}
Visual Color	**Figure 1A**	**Figure 1B**	**Figure 1C**	**Figure 1D**	**Figure 1E**

Abbreviations: T, treatment; see material and methods (Table 2); L*: lightness; a*: redness; b*: yellowness; C*: chroma value; H°: hue angle; BI: browning index; ΔE: color changes. L*, b*, and b* were obtained directly from the Hunter instrument. C, H°, BI, and ΔE were calculated following the formulas described earlier in the Materials and Methods (Section 2.8). Different superscripted letters (a–e) between any two means within the same row indicate significant differences at $p < 0.05$.

3.7. Sensory Attributes

The sensory attributes based on the standard 9-hedonic scale were tested, as shown in Table 7. The most liked treatment in terms of taste was T1, followed by T2 (8.6 ± 0.24 and 7.4 ± 0.24 scores, respectively), while treatments containing higher ratios of oat beverage, T4 and T5, recorded the significantly lowest sensory scores (3.4 ± 0.81 and 2.2 ± 0.49 scores, respectively). After 7 to 14 days of storage, the taste scores slightly increased in T1 and T2 (from 8.2–7.6 to 8.4–8.6). However, such an increase was optimum to day 14, and at the end of the storage period, the taste scores of T1 and T2 decreased from 8.4–8.6 to 8. These results show that T2 recorded higher taste scores after day 14 compared to T1. The other treatments (T3–T5) consistently showed the lowest taste scores throughout the storage period, with an average of 7, 3, and 2 in T3, T4, and T5, respectively. Regarding color scores, T1 and T2 were also the most liked, with an average of 8.4 out of 9, followed by T3 (7.6 out of 9), while T4 and T5 recorded the lowest color scores, reaching 4–3 out of 9. In terms of aroma, T1 was the most liked treatment with an average of 7.7 scores, followed by T2 (7.3 out of 9), while T3–T5 recorded the least significant aroma scores (3–2 average scores). Interestingly, aroma scores had declined in T1 after 21 days of storage (from 7.6 to 7.4), while T2 showed an increase (from 7.4 to 7.8). Furthermore, dairy beverages' textures and smoothness are other critical attributes affecting their acceptance; interestingly, T2 recorded higher scores in terms of texture, followed by T1. In general, the overall acceptability of the treatments showed higher scores in T1 (8 average scores), followed by T2 (7.8 average scores), while T3–T5 recorded the lowest overall scores (3–2 average scores). In addition, it should be noted that after 21 days of storage, most sensory scores recorded declines, as shown in Table 7.

Table 7. Sensory attributes during storage (3 ± 1 °C, 21 days) of fermented camel milk beverage incorporated with oats and date palm fruit (mean ± SE, *n* = 10).

Attribute *	Storage Period (Days)	Treatments				
		T1	T2	T3	T4	T5
Taste	1	8.6 ± 0.24 ^{aA}	7.4 ± 0.24 ^{bB}	6.8 ± 0.58 ^{bcB}	3.4 ± 0.81 ^{bC}	2.2 ± 0.49 ^{bD}
	7	8.2 ± 0.58 ^{aA}	7.6 ± 0.51 ^{bA}	7.6 ± 0.60 ^{aB}	5.2 ± 1.24 ^{aC}	2.2 ± 0.73 ^{bD}
	14	8.4 ± 0.24 ^{aA}	8.6 ± 0.24 ^{aA}	7.4 ± 0.51 ^{abB}	3.2 ± 0.20 ^{bC}	3.2 ± 0.86 ^{aC}
	21	8.0 ± 0.45 ^{aA}	8.0 ± 0.45 a^{bA}	6.6 ± 0.75 ^{cB}	2.2 ± 0.20 ^{cC}	1.0 ± 0.00 ^{cD}
	Mean	8.30 ± 0.19 ^{A}	7.90 ± 0.2 ^{A}	7.10 ± 0.3 ^{B}	3.50 ± 0.43 ^{C}	2.15 ± 0.33 ^{D}
Color	1	8.2 ± 0.49 ^{aA}	8.4 ± 0.40 ^{aA}	7.6 ± 0.60 ^{aA}	4.4 ± 0.68 ^{bB}	2.8 ± 0.37 ^{cC}
	7	8.6 ± 0.40 ^{aA}	8.2 ± 0.37 ^{aAB}	7.6 ± 0.40 ^{aB}	5.4 ± 0.98 ^{aC}	3.8 ± 0.49 ^{bD}
	14	8.4 ± 0.24 ^{aA}	8.6 ± 0.24 ^{aA}	7.4 ± 0.24 ^{aB}	5.6 ± 0.68 ^{aC}	3.8 ± 1.11 ^{bD}
	21	8.4 ± 0.24 ^{aA}	8.4 ± 0.24 ^{aA}	8.0 ± 0.32 ^{aA}	4.4 ± 1.12 ^{bB}	4.8 ± 1.16 ^{aB}
	Mean	8.40 ± 0.17 ^{A}	8.40 ± 0.15 ^{A}	7.65 ± 0.20 ^{A}	4.95 ± 0.43 ^{B}	3.80 ± 0.43 ^{C}
Aroma	1	8.0 ± 0.45 ^{aA}	7.0 ± 0.63 ^{aA}	5.8 ± 0.86 ^{bB}	3.2 ± 0.73 ^{aC}	2.2 ± 0.73 ^{aC}
	7	8.0 ± 0.77 ^{aA}	7.2 ± 0.73 ^{aA}	7.0 ± 0.63 ^{aA}	3.8 ± 0.73 ^{aC}	3.0 ± 0.55 ^{aC}
	14	7.6 ± 0.68 ^{aA}	7.4 ± 0.75 ^{aAB}	6.4 ± 1.03 ^{abB}	2.8 ± 0.37 ^{aC}	2.6 ± 0.81 ^{aC}
	21	7.4 ± 0.87 ^{aA}	7.8 ± 0.37 ^{aAB}	6.8 ± 0.37 ^{aB}	3.6 ± 0.75 ^{aC}	1.0 ± 0.00 ^{bD}
	Mean	7.75 ± 0.33 ^{A}	7.35 ± 0.3 ^{AB}	6.5 ± 0.37 ^{B}	3.35 ± 0.32 ^{C}	2.20 ± 0.33 ^{D}
Texture	1	8.0 ± 0.55 ^{abA}	7.6 ± 0.24 ^{bA}	6.6 ± 0.75 ^{bB}	3.4 ± 0.87 ^{bC}	2.8 ± 0.73 ^{bC}
	7	7.6 ± 0.68 ^{bA}	8.0 ± 0.77 ^{abA}	7.4 ± 0.40 ^{abA}	5.0 ± 1.18 ^{aB}	4.4 ± 1.21 ^{aB}
	14	8.6 ± 0.24 ^{aA}	8.6 ± 0.24 ^{aA}	8.0 ± 0.00 ^{aA}	5.2 ± 0.66 ^{aB}	2.8 ± 0.58 ^{bC}
	21	8.4 ± 0.40 ^{abAB}	8.6 ± 0.24 ^{aA}	7.6 ± 0.40 ^{aB}	4.0 ± 0.89 ^{bC}	1.4 ± 0.24 ^{cD}
	Mean	8.15 ± 0.24 ^{A}	8.20 ± 0.22 ^{A}	7.40 ± 0.24 ^{A}	4.4 ± 0.46 ^{B}	2.85 ± 0.43 ^{C}
After Taste	1	8.4 ± 0.24 ^{aA}	7.6 ± 0.60 ^{bAB}	6.6 ± 1.03 ^{bB}	4.2 ± 0.73 ^{bC}	2.0 ± 0.45 ^{bcD}
	7	8.0 ± 0.77 ^{aA}	6.6 ± 1.44 ^{cB}	7.4 ± 0.75 ^{abAB}	5.2 ± 1.36 ^{aC}	2.4 ± 0.68 ^{bD}
	14	8.6 ± 0.24 ^{aA}	8.6 ± 0.24 ^{aA}	8.2 ± 0.20 ^{aA}	5.8 ± 0.73 ^{aB}	4.2 ± 0.80 ^{aC}
	21	8.4 ± 0.24 ^{aA}	8.4 ± 0.24 ^{abA}	8.0 ± 0.32 ^{aA}	4.0 ± 0.84 ^{bB}	1.4 ± 0.24 ^{cC}
	Mean	8.35 ± 0.21 ^{A}	7.8 ± 0.41 ^{A}	7.55 ± 0.34 ^{A}	4.8 ± 0.47 ^{B}	2.5 ± 0.36 ^{C}
Overall Acceptability	1	8.6 ± 0.24 ^{aA}	8.00 ± 0.63 ^{aA}	4.6 ± 0.75 ^{cB}	4.00 ± 0.84 ^{Ba}	2.2 ± 0.37 ^{aC}
	7	8.00 ± 0.77 ^{abA}	7.4 ± 0.68 ^{aA}	7.2 ± 0.66 ^{aA}	4.00 ± 1.55 ^{aB}	2.00 ± 0.77 ^{aC}
	14	8.4 ± 0.24 ^{abA}	8.2 ± 0.49 ^{aA}	6.4 ± 0.75 ^{abB}	2.6 ± 0.24 ^{bC}	2.2 ± 0.37 ^{aD}
	21	7.6 ± 0.4 ^{bA}	7.6 ± 0.4 ^{aA}	6.00 ± 0.71 ^{bB}	2.2 ± 0.20 ^{bC}	1.00 ± 0.00 ^{bD}
	Mean	8.15 ± 0.23 ^{A}	7.8 ± 0.27 ^{A}	6.05 ± 0.4 ^{B}	3.2 ± 0.45 ^{C}	1.85 ± 0.24 ^{D}

*: based on the standard 9-hedonic scale. Abbreviations: T, treatment; see material and methods (Table 2). Significant difference at $p < 0.05$ is indicated by different subscripted letters, (a–c) between any two means within the same column, and (A–D) between any two means within the same row.

4. Discussion

Camel milk-based products have shown remarkable interest in manufacturing innovative functional products in recent years. The current work used camel milk, oat beverage, and Sukkari date paste to develop enhanced camel milk using ABT-5 starter culture. The study treatments were prepared by replacing camel milk with oat beverage in concentrations of 0, 25, 50, 75, and 100%, providing five treatments (T1–T5), each containing 10% of Sukkari dates paste as previously recommended [16].

The supplementation with oat beverage provided novel milk samples with enhanced functional properties. The total phenolic content and antioxidant activity were remarkably higher with increased ratios of oat beverage, a difference of more than 200% was observed from T1 to T5. Oats have been reported to contain excellent amounts of total phenolics, which explains the significant difference observed [21,22]. Phenolics are plant-based compounds known for their strong antioxidant potential and are found in various foods and beverages [33]. Fermentation processes can lead to major improvements in the phenolic

content; the activity of microbial enzymes during fermentation, such as glycosidases, can facilitate the liberation of bound phenolics, resulting in their release into the fermentation medium. In addition, other compounds found in the raw materials can lead to the breakdown of precursor molecules during fermentation leading to the formation of phenolic compounds [33–35]. In the current work, the treatments showed significant differences in their release of more phenolics during storage periods; despite the major amounts noted in treatments containing higher ratios of oat beverage, treatments with higher ratios of camel milk (75–100%) showed more positive progress, indicating that probiotic enrichment is more active with dairy products than cereals. Accordingly, results showed a decrease of 19–41% in microbial growth observed with increased ratios of oat beverage. The presence of lactose in dairy products as the primary carbohydrate fraction can boost the fermentation process, as lactose is rapidly broken down to lactic acid by the lactose-utilizing bacteria, such as the *Lactobacillus* and *Streptococcus* species [36,37]. Conversely, cereals consist of complex carbohydrates such as starch, which requires enzymatic metabolization to be broken into simple sugars. Lactose-utilizing bacteria can not directly break down starch, but their activity provides an acidified environment, leading to more favorable conditions for starch-degrading enzymes [38–40]. Therefore, fermented cereals by such bacteria may require longer time to thrive than dairy products, which explains the significant difference between the treatments in releasing more phenolics during storage periods. However, T2 (25% of oat beverage) showed a higher release of phenolics compared to T1, which was also accompanied by higher microbial growth by 2–7% compared to that observed in T1. Suggesting that small amounts of oat beverage might enhance the bacteria's activity in fermented dairy milks. Adding more than 25% but less than 50% of oat beverage is suggested for further investigations.

Furthermore, the supplementation with oat beverage also showed other enhancements; cereals such as oats contain significant amounts of high-quality fiber, mainly β-glucans [21,23]. The prepared treatments showed significant increases in β-glucan content dose-dependently by 4–17 times. However, due to microbial activity during the storage period, the β-glucan content showed a decline. Fermentation processes have been shown to affect β-glucan content negatively [13]; some certain species of bacteria, such as *Lactobacillus,* may primarily prefer β-glucan for their growth due to their ability to produce β-glucanases, the specific enzymes capable of metabolizing β-glucan [41]. However, the final content recorded after 14 days of storage reached 0.00, 0.01, 0.08, 0.13, and 0.15 g 100 mL^{-1} WW (equivalent to 0.00, 0.05, 0.71, 1.29, and 1.95 g 100 g^{-1} DW) in T1–T5, respectively; such minimum quantities might be beneficial in providing some health-promoting effects. Anti-inflammatory effects were observed after the dietary supplementation of β-glucan at 0.1 g kg^{-1} BW [42]. Another study showed that 0.4 g of oat β-glucan reduced the blood glucose peak-rise by 20% [43]. However, the minimum amounts recorded in the current work need further enhancements to reach at least 0.1 g 100 g^{-1} in T2, as the higher amounts were only observed in T4 and T5, which showed limited microbial activity, as described earlier.

On the other hand, the prepared treatments showed a reduction in protein and fat content with decreased ratios of camel milk, though replacing camel milk with 25% of oat beverage (T2) helped to maintain sufficient amounts of protein and fats (3.3% and 2.6%, respectively), compared to that recorded in T3–T5 (2.6–1.2% and 1.8–0.38 of protein and fat, respectively). The protein content in whole cow's milk typically ranges from 3.2% to 3.4%, while the fat content ranges from 3.5% to 4% [44,45]. Camel's milk, in contrast, often contains 3.4–4.5% of protein and 1.2–6% of fat [7,46]; in the current work, raw camel's milk had 3.8% and 2.7% of protein and fat, respectively. Therefore, the content recorded in T2 can be considered excellent for a wide range of individuals, such as hypercholesteremic ones, meeting their needs for protein with a low fat content. Furthermore, sufficient amounts of mineral content were observed in T2 compared to other treatments that recorded major decreases.

Interestingly, a significant increase in iron content by 30% was also recorded in T2. Oats and date fruit contain some amounts of iron, which could contribute to such enhancement; rolled oats used in the current work had 3.9 mg 100 g^{-1} of iron, while dates contained 1 mg 100 g^{-1}. A similar increase in iron content was recorded in fermented camel milk after the supplementation of date syrup [7]. However, T1 contained the exact amount of date paste as that in T2, suggesting that increased iron is highly linked to oat supplementation. However, the observed increase in iron content showed a decline with increased ratios of oat beverage (50–100%); a possible explanation for the higher iron content recorded only in T2 might be related to the higher microbial activity that led to more iron bioavailability. Cereals, such as oat, contain some natural complex antinutritive compounds, mainly phytic acid, that can bind to minerals like iron, thus limiting their availability. Lactose-utilizing bacteria can produce phytase enzymes during their growth activity, leading to phytic acid degradation, hence providing more iron [47–49]. Therefore, fewer phytase enzymes were produced due to the limited microbial activity observed in T3–T5 compared to T2. The measurement of phytic acid is suggested for further studies.

From another point of view, the sensory attributes of any food or beverage product are a critical factor affecting its acceptance. The sensory attributes in the current work were investigated based on the standard 9-hedonic scale; the most liked treatments in terms of taste were T1 and T2. More enhancements in taste scores during the storage period were also observed in T1 and T2, which could be related to the higher microbial activity that potentially leads to different complex flavor development. For instance, lactic acid production provides fermented dairy milk with its characteristic tangy flavor, the more lactic acid produced, the tangier flavor observed [50]. Accordingly, the results showed that T1 and T2 recorded a higher acidity of 1 to 1.19%. T1 and T2 also recorded higher color, aroma, and aftertaste scores. However, T2 showed higher texture scores than T1, which had an extremely thick texture close to that of yogurt. This could be explained by the higher protein content recorded in T1 compared to T2. Milk proteins, mainly casein, can form a gel-like structure due to their coagulation during fermentation, resulting in the formation of crude that contributes to a thicker structure similar to that observed in yogurt and cheese [51]. On the other hand, it should be considered that after 21 days of storage, most sensory scores recorded significant declines, indicating that these fermented treatments must not be consumed after being stored for longer than 14 days. Consistently, declines in other properties in the current work were also observed after 21 days of storage, as indicated earlier. Similar declines in other characteristics were reported in fermented oat beverages after 21 days of storage [52]. Multiple other studies indicated that the optimum shelf life for fermented milk products is limited to 14–15 days [7,53].

5. Conclusions

The current work investigated the effects of supplementing fermented camel milk with oat beverage and date palm fruit. The supplementation of 25% of oat beverage resulted in multiple enhancements, the microbial activity during storage periods at 4 °C showed higher activity by 2–7% compared to that observed in control treatment containing 100% camel milk (on average, 8.00 vs. 7.77 Log_{10} CFU mL^{-1}). Consequently, the total phenolic content and antioxidant activity showed a significant increase. A slight increase in β-glucan content was also observed, but further enhancements are required to reach at least ≥0.1 g 100 g^{-1}. Furthermore, an interesting increase in iron content was observed, potentially due to increased phytase enzymes during the microbial activity. Moreover, 25% of oat beverage also showed sufficient amounts of protein with a low fat content, suggesting it is beneficial for hypercholesteremic individuals. The sensory attributes of this addition recorded higher scores in almost all sensory attributes, while other treatments containing 50–100% of oat beverage recorded the least significant scores, reaching 1–2 out of 9. For future studies, supplementing with more than 25% but less than 50% of oat beverage is suggested. The addition of other varieties of date fruit or other natural sweeteners can also be investigated.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/fermentation9100864/s1, Figure S1: Changes in generated color after the β-glucan assay compared to standard and blank; red colors indicate the presence of β-glucan.

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