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Production of a Functional Yogurt Drink Enriched with Black Rice Beverage

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ABSTRACT

There are a many previous studies focusing on the production of probiotic yoghurt based on raw materials like oat and soy milk; however, little is known about the usage of black rice beverage in fermented dairy products. In the present study, four different types of yoghurt drinks were produced, where cow's milk yogurt was replaced with 10, 20, 30, and 40% of black rice beverage in the yogurt drink formula and stored for 15 days at 4°C. Physical, chemical, phytochemical, microbiological, and sensory characteristics of the drink samples were performed at the zero, 5, 10 and 15 days of the storage. We found that the addition of black rice beverage to yoghurt drink formula significantly increased total solids, protein, anthocyanin, phenolics, antioxidant activity, pH, and viscosity values but decreased the values of acidity, fat, ash, and acetaldehyde of yoghurt drinks. The addition of black rice beverage increased the total bacterial and bifidobacteria counts. In the sensory analysis, scores decreased as the black rice beverage proportions in yoghurt drink formula was increased. Based on the panelists' report, T1 and T2 samples (Replaced cow's milk yogurt with 10 and 20% of the black rice beverage in the yogurt drink formula, respectively) were the closest samples to the control sample (Yogurt drink made from 100% cow's milk). The consumption of such products is continuously increasing as the customers' tendency to consider them as functional products rather than traditional food products increase.

Keywords: fermented milk, Oryza sativa Linn, Physical, microbiological, sensory characteristics.

INTRODUCTION

Foods that have undergone fermentation have been a staple of human diets for thousands of years. Yoghurt is a popular fermented milk product that comes in a variety of flavours and forms (Tamime & Robinson, 2007: Atwaa *et al*, 2022). A popular dairy product called yoghurt has alcohol in it due to a chemical reaction. Its nutritional content and other qualities related to vitamins, proteins, and other food ingredients make it a popular choice. The inclusion of (silver metal/essential nutrients), phosphorus, potassium, high biological value vitamins, proteins, and critically necessary fatty acids have been related to the health benefits of yoghurt. Yoghurt is a well-known probiotic carrier, even though bifid small germ and lactobacillus-enriched yoghurts are two of the most popular types of functional foods. A number of health benefits of yoghurt consumption have been linked to research, such as the prevention of weakening and thinning bones, heart and blood vessel disease, and hyperglycemia, as well as improvements to general gut health and modulation of the immune system (Hadjimbei *et al*, 2020). For the last 20 years at least, there has been a significant global increase in the consumption of yoghurt. A variety of products with different flavours, health statuses, and other attributes have been developed as a result of yoghurt recipes branching out or being done differently by producers due to their ability to create intriguing new products and consumers' demand for healthier and tastier products (Basiony *et al*, 2023).

To get the desired colour, flavour, and texture, yoghurt drinks are made by diluting the yoghurt with sugar, juice, or pectin dispersion in water (Tamime & Robinson, 2007). According to Mordorintelligence (2022), the worldwide yoghurt drink market is projected to increase at a compound annual growth rate of 4.8% from 2020 to 2025. There are three types of yoghurt drinks: pasteurised homogenised stirred yoghurt (which has a shelf life of 1-2 months), ultra-high temperature-treated homogenised stirred yoghurt (which has a shelf life of up to several months), and homogenised stirred yoghurt with a shelf life of 2-3 weeks. Yoghurt drinks are increasingly being made with stabilisers as whey off is thought to be a problem with the product (Arab *et al*., 2022). Drinks made from stirred, low-viscosity yoghurt that are enjoyed as refreshing beverages are categorised as yoghurt drinks. The Food and Drug Administration states that yoghurt drinks should have a minimum of 8.25% milk solids without fat, a maximum of 3.25% fat for the full-fat yoghurt drinks, less than 0.5% fat for the free-fat yoghurt drinks, and 2% fat for the low-fat yoghurt drinks. Yoghurt drinks have 3.5% fat, 3.8% protein, 8% sugar, and 15% sterile fruit by chemical makeup (Tamime & Robinson, 2007; Abdeldaiem *et al*, 2023). Yoghurt products are being enhanced with various fruit and vegetable ingredients, like apple concentrates, carrots, lemon, orange concentrates, pineapples, raspberries, and strawberries, which has raised consumer demand for yoghurt drinks (Sawant, *et al*., 2015; Kowaleski *et al*., 2020; Wang, *et al*., 2020; ˇSeregelj *et al*., 2021).

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Various fruit and vegetable additions are increasingly used in the yoghurt recipes (Ni *et al*, 2018). The addition of vegetable and fruit ingredients has a major impact on the physicochemical (related to vitamins, protein, etc.) and characteristics of yoghurt (Oliveira *et al*, 2015). These effects are specific to vegetable and fruit additions and are related to the non-food and food-like components of the fruit. For example, phenolic compounds are commonly added to yoghurts by the addition of fruit and vegetable additions (Rodríguez *et al*, 2021). It was widely known that phenolic compounds interact with milk proteins to form protein–polyphenol complexes, which add to the phenolic compounds' characteristics in relation to other food ingredients like protein, vitamins, and so on. New functional dairy products that could satisfy customer demands (related to goods or services) might be produced as a result of this addition (to anything else) (Basiony *et al*., 2023).

Black rice is inexpensive, widely accessible, and known to contain anthocyanin chemicals, which have a variety of pharmacological properties, including antioxidant activity. Cyanidine-3-glycosides and peonidine-3-glycosides are the primary anthocyanin components of black rice (*Oryza sativa* var. *glutinosa*) (Winarti *et al*., 2020). Anthocyanins are thought to be strong antioxidants that have been linked to preventive effects against diabetes, atherosclerosis, inflammation, and cancer (Aboonabi *et al*., 2020; Nikbakht *et al.*, 2021; Sapian *et al.*, 2022). The red, purple, and blue hues found in many plant materials are attributed to a class of water-soluble natural pigments called anthocyanins, which are members of the vast flavonoid family (Raghvendra *et al*., 2011; Alappat & Alappat, 2020). To try and prevent cancer, one can make use of foods high in anthocyanins. Purple sweet potatoes and black sticky rice tape are two foods rich in anthocyanins. Black rice has an antioxidant activity of 70.2% grammes and anthocyanin content of 257 ppm/100 g (Fauziyah *et al*. 2018: 2024). Black rice has been used as a raw material in various studies to create products with high anthocyanin content. Black rice was used to make cookies whose anthocyanin levels were 5.72 mg/100 g (Moviana *et al.*, 2022). Black glutinous rice was used as a primary ingredient to make eggrolls in which the anthocyanin levels are 22.64 mg/100 g (Sukowati *et al*., 2023).

A small number of research have examined the use of black rice beverage in fermented dairy products, but most have concentrated on the creation of probiotics and fermented dairy products manufactured using vegetable-based raw materials like oats and soy. Here, we aim to create fermented dairy products using cow milk and black rice beverage mixture, or black rice beverage instead of milk. Probiotic yoghurt drink manufacturer used black rice beverage, a significant raw food source considered globally, to improve the drink's sensory qualities and boost its commercial popularity. There aren't many studies worldwide that concentrate on making these kinds of things. Furthermore, diets and food compositions are required for people with a variety of health issues. From this angle, we sought to improve the physical, chemical, microbiological, and sensory qualities of black rice beverage—a fermented product recently introduced in Egypt—by combining probiotic adjunct cultures with regular yoghurt culture.

MATERIALS AND METHODS

Materials and Reagents:

Black rice (*Oryza sativa* Linn.) was obtained from The Sakha Agricultural Research Station, Kafr El-Sheikh Governorate, Egypt. Fresh cow standardised milk with 3% fat content was obtained from The Dairy Technology Unit, Food Science Department, Faculty of Agriculture, Zagazig University. Starter cultures including *Lactobacillus bulgaricus* and *Streptococcus salivaris ssp. thermophillus* as yoghurt starters and *Bifidobacterium bifidum* B-12 as a probiotic strain were purchased from Hansen's Laboratories, Copenhagen, Denmark. Additionally, gallic acid and 1,1-diphenyl-2-picrylhydrazyl (DPPH) were acquired from Sigma (St. Louis, MO, USA). Moreover, analytical grade reagents and substances were utilized

Preparation of black Rice beverage:

The high-quality black rice beverages involving drying the rice and then submerging it in water to absorb moisture were made based on a technique previously described (Tang *et al*, 2020). The rice was then given a 1- to 1.5-hour steam to help the starch into the sticky rice gelatinize. The rice paste was statically cooled before being blended with water (200 g rice paste + 400 ml water) (Atwaa *et al*., 2019). The blended rice was then sieved twice to provide a good texture and cooked at 95 °C for 10 minutes to produce rice beverage

Determination of phytochemical properties

The total phenolic content (TPC) was measured by Folin–Ciocalteu assay using Gallic acid as a standard (Kaur and Kapoor, 2002) with some modifications. Briefly, 1 mL of diluted (1:10) FC reagent was combined with 100 µL of various concentrations of a test sample. After 10 minutes, 1 mL of 7.5% (w/v) sodium carbonate solution was then added to the mixture followed by incubation, for 90 minutes a.t dark. The phenolic content was estimated by measuring the absorbance at 725 nm, and expressed as mg of gallic acid equivalents per 100 g. The DPPH radical scavenging activity was estimated by measuring the absorbance of the purple-colored DPPH solution at 517 nm by a spectrophotometer (Thermo Scientific, Wilmington, NC, USA) (Brand-Williams *et al*, 1995). The following formula was used to determine the scavenging activity:

$$\textbf{Scavenging activity (\%)} = 1 - (Abs_{sample} - Abs_{blank})/Abs_{control} \times 100.$$

Determination of total anthocyanin Content

The total anthocyanin (TAC) content was measured spectrophotometrically at 525 nm after extracting anthocyanins with acidified methanol (methanol and HCl, 85:15, v/v) and expressed as mg of cyanidin 3-glucoside equivalent per 100 g (Wang *et al.*, 2014; Wu *et al*., 2015).

Yoghurt drink manufacture

To the standardised cow milk (3.0%. fat), sugar was added and the mixture was heated at 80°C for 30 minutes and then, gelatin (0.25%) was added at 38°C. The milk was allowed to cool down and infused with a 2% yoghurt culture and a 5% probiotic culture of *B Bifidum*. It was then incubated at 37 °C until the pH dropped to 4.6, resulting in full coagulation. The generated yoghurt was chilled to 4°C. Several experiments were carried out using various quantities of set yoghurt, sugar, black sticky rice beverage, and boiling water (Table 1). All treatments underwent vigorous whipping and were promptly transferred into 200 ml sterile glass bottles and stored in at 4°C. The physico-chemical, rheological, microbiological, and sensory qualities of these yoghurt preparations were examined at 0, 5, 10, and 15 days.

Table 1. Different Formula used in black Sticky Rice beverage -yoghurt drink development

Treatment	Yoghurt %	Sugar %	Black Rice beverage%	Water %
C	80	5	0.0	15.0
T1	70	5	10.0	15.0
T2	60	5	20.0	15.0
T3	50	5	30.0	15.0
T4	40	5	40.0	15.0

Methods of analysis:

The yoghurt samples' titratable acidity, ash content, total solids, fat, and total protein were measured in accordance with spell out AOAC (AOAC, 2010). The pH of the samples was measured by digital pH meter (HANNA, Instrument, Portugal)..The acetaldehyde concentration was determined based on a published protocol (Less and Jago, 1969) dusing a standard curve, which varied from 1 to 30 μmol/100 mL. Viscosity was measured at 30 °C using the Rotational Viscometer Type Laboratory. Line Model 5437 (Aryana, 2003) and the readings were expressed in poise (Pa.s).

Microbiological Examinations

The bacteria were quantitated using the conventional pour plate method as follows:. 9.0 mL of 0.85% sterile saline was added to each sample (1.0 mL), and additional dilutions were performed in accordance with the specifications. Total bacterial counts were performed on yoghurt drink samples using the previously published procedure (A.P.H., 2001). The counting of *B. bifidum* was carried out on Bifidobacterium agar during anaerobic incubation at 37 °C for 72 hours. Plates with 30–300 colonies were used for the microbial count enumeration and the results were expressed as log number of colony-forming units per millilitre, or Log cfu/mL.

Sensory analysis

To assess the probiotic yoghurts' suitability for consumption, sensory study was performed using, the grading system as previously described (Bodyfelt *et al*, 1998). A qualified panel of faculty members and graduate students from the dairy technology department of Zagazig University Faculty of Agriculture participated in the sensory analysis. The evaluation standards outlined in TS-1330 were taken into account for grading. The panelists were handed evaluation forms with a grade range of 1 to 5 and instructed to complete them in accordance with these criteria.

Statistical analysis:

Four distinct yoghurt drink varieties were made in the study twice. Analysis of Variance was utilised for the statistical examination of the results, and the Duncan Test was employed to identify the various groups. Consequently, SPSS version 19.0 statistical analysis software was employed.

Results and discussion

Proximate composition of black rice beverage:

The approximate chemical composition of the black rice beverage was presented in Table 2. The total solids, protein, fat, and ash contents of the black rice beverage were 24.80, 3.55, 0.95, and 0.54 g/100 g, respectively. The total phenolic content, total anthocyanin content and the % DPPH inhibition of the black rice beverage were 1640.60 mg GAE/100 g, 164.50 mg/100g, and 92.70%, respectively. This is the first study that addresses the chemical composition of the rice beverage prepared. However, the chemical composition of black rice was previously reported by Fatchiyah *et al*., (2020) which was as follows: 12-13% moisture, 9-10% protein, 2.7-2.85% fat, and 1.20 - 1.60% ash. As previously reported, black rice and its extracts contained a high amount of total phenolic substances, total anthocyanins, and high antioxidant activity (Fatchiyah *et al*., 2020; Winarti *et al*., 2021; Phanumong and Prommajak, 2023).

Table 2. Approximate chemical composition, total phenol, total anthocyanin and % DPPH Inhibition of black rice beverage

Components (%)	black rice beverage
Total solids	24.80±1.14
Protein	3.55±0.36
Fat	0.95±1.05
Ash	0.54±0.03
Total Phenol (mg GAE/100g)	1640.60±4.55
% DPPH Inhibition	92.70±1.94
Total Anthocyanin Content (mg/100g)	146.50±2.06

Chemical compositions of yoghurt drink containing black rice beverage:

Samples of yoghurt drinks were subjected to chemical analysis both when 0 day and after 15 days of storage. Table 3 shows the results with standard deviations. On 0 day and 15 days of storage, there was a statistically significant difference ($p \leq 0.05$) in the dry matter contents of the yoghurt drink samples. The samples' dry matter concentrations ranged from 15.40 to 22.88%. It was noted that replacing yogurt with black rice beverage in the prepared yogurt drink mixture led to an increase in the percentage of dry matter in the final product, As the replacement ratio increased, the dry matter content increased. For all treatments, an increase in the percentage of dry matter was also observed with increasing storage period. There are some variances as well as some partial similarities between our results and the dry matter data (El-Shazly, 2016). The dry matter contents are influenced by the types of raw milk utilised in the production of rice milk and dry matter, the procedure employed during the manufacturing, and the degree of lactose fermentation cultures (Uzuner *et al*., 2016).

Following the 15-day storage period, the samples' protein levels ranged from 3.08 to 3.52%. The protein content of yoghurt drink samples was significantly ($p \leq 0.05$) different between the 0-day and 15-day storage samples. The replacing yogurt with black rice beverage in the prepared yogurt drink mixture led to a non-significant increase in the percentage of protein in the final product, this is a result of the similarity in the percentage of protein in the yogurt milk and the black rice beverage (Table 2). An increase in the percentage of protein was also observed with increasing storage period for all treatments. The control and other yoghurt drink samples' protein contents were confirmed to be in compliance with the Fermented Milks Regulations' minimum protein concentration of 3%. According to earlier research, protein levels ranged from 2.66 to 8.38 percent (Sert & Kalyoncu, 2006; Uzuner *et al*., 2016). The protein values from our studies were similar to these findings.

The samples' fat and ash concentrations ranged from 3.06 to 2.02% and 0.60 to 0.92%, respectively. At zero and after 15 days of storage, there was a statistically significant difference ($p \leq 0.05$) in the fat and ash levels of the yoghurt drink samples. The replacing yogurt with black rice beverage in the prepared yogurt drink mixture led to a decrease in the percentage of fat and ash in the final product, and that this decrease increased with an increase in the replacement percentage. An increase in the percentage of fat and ash were also observed with increasing storage period for all treatments. The results obtained were similar to those of El-Shazly (2016) who observed an increase in the percentage of dry matter and protein and a decrease in the percentage of fat and ash as a result of fortifying yogurt with cooked rice.

Table 3. Chemical composition of yoghurt drink containing black rice beverage stored in refrigerator (~5°C) for 15 days

Components (%)	Storage period (Day)	Treatments				
		C	T_1	T2	T3	T4
Total solids	0	15.40±0.24^{h}	16.70±0.18^{g}	18.0±0.12^{e}	19.20±0.14^{d}	20.60±0.08^{c}
	5	15.94±0.20^{h}	17.28±0.20^{f}	18.84±0.26^{d}	20.14±0.16^{c}	21.28±0.22^{b}
	10	16.82±0.16^{g}	18.16±0.18^{e}	19.78±0.30^{c}	20.92±0.24^{b}	22.04±0.18^{a}
	15	17.70±0.22^{f}	19.12±0.12^{d}	20.66±0.14^{c}	21.74±0.16^{b}	22.88±0.20^{a}
Protein	0	3.08±0.06^{e}	3.14±0.05^{e}	3.20±0.04^{de}	3.25±0.06^{cd}	3.32±0.08^{c}
	5	3.18±0.04^{de}	3.22±0.03^{d}	3.28±0.06^{cd}	3.33±0.04^{c}	3.38±0.05^{b}
	10	3.24±0.08^{d}	3.28±0.04^{cd}	3.35±0.05^{bc}	3.40±0.08^{b}	3.46±0.06^{ab}
	15	3.36±0.03b^{c}	3.34±0.05^{c}	3.42±0.07^{b}	3.48±0.04^{a}	3.52±0.02^{a}
Fat	0	2.85 ±0.02^{c}	2.66±0.03^{e}	2.45±0.04^{fg}	2.24±0.02^{h}	2.02±0.01^{i}
	5	2.92±0.03^{b}	2.74±0.01^{d}	2.50±0.02^{f}	2.30±0.04^{gh}	2.24±0.03^{h}
	10	2.98±0.01^{ab}	2.80±0.02^{cd}	2.58±0.04e^{f}	2.36±0.01^{g}	2.36±0.02^{g}
	15	3.06±0.02^{a}	2.86±0.03^{c}	2.66±0.01^{e}	2.48±0.02^{f}	2.42±0.04^{fg}
Ash	0	0.76±0.01^{cd}	0.74±0.02^{c}	0.70±0.01^{d}	0.65±0.02^{e}	0.60±0.01^{f}
	5	0.82±0.01^{bc}	0.78±0.02^{cd}	0.75±0.02^{c}	0.70±0.02^{d}	0.65±0.01^{e}
	10	0.88±0.02^{ab}	0.84±0.01^{b}	0.80±0.02^{c}	0.76±0.01^{c}	0.70±0.02^{d}
	15	0.92±0.01^{a}	0.90±0.01^{a}	0.84±0.01^{b}	0.80±0.01^{c}	0.76±0.02^{cd}

Means in the same row that are denoted by several little letters differ significantly ($p \leq 0.05$). Each yoghurt sample underwent a triplicate analysis after each experiment was carried out in triplicate. C: yoghurt drink made from cow milk as a control, T1: Yoghurt drink containing 10 % black Rice beverage, T2: Yoghurt drink containing 20 % black Rice beverage, T3: Yoghurt drink containing 30 % black Rice beverage, T4: Yoghurt drink containing 40 % black Rice beverage.

Titratable acidity, pH, Viscosity and acetaldehyde values of yoghurt drink containing black rice beverage:

Table 4 provided the average lactic acid percentage values together with standard deviations for the probiotic yoghurt samples. The difference in lactic acid (%) readings on the 0, 5, 10, and 15 days was found to be significant ($p \leq 0.05$). The samples' lactic acid levels rose over the course of storage, despite the fact that there were notable variations across storage days. Throughout storage, probiotic yoghurt samples' lactic acid (%) concentrations ranged from 0.62 to 1.12%. The Food Codex Fermented Milks Regulations state that the lactic acid content should range from 0.6% to 1.5%. Every treatment's level has complied with the rules and maintained that compliance during the storage time. The acidity values dropped as the rates of rice drinks replacing yoghurt increased. Typically, the control sample had the greatest level of lactic acid detected, whereas T4 had the lowest. Total acidity values increased in all of the samples as a result of periodic increases during the storage period. This was linked to the culture bacteria's ongoing generation of acid. The products' shelf life can be determined in part by observing the shift in acidity upon incubation. Additionally, an increase in protein, phosphate, citrate, lactate, and certain minerals along with an increase in dry matter could be the cause of the rise in titratable acidity (Tamime & Robinson, 1999). The pH values also took an opposite direction to the acidity trend in all treatments and during the storage period, as the pH values increased with the increase in the rate of replacing yogurt with rice beverage. The control sample had the highest pH values, while T4 had the lowest pH values. Lactic acid levels and pH values were found to be greater in samples containing soy milk or rice milk in a study on yoghurts made from these milks (Lee & Yoo, 2011: Uzuner *et al*, 2016).

Table 4 also provided the average viscosity values of the probiotic yoghurt samples. After the samples were stored for 15 days, their viscosity was measured and found to range from 3.40 to 3.86 Pa. The viscosity values dropped as the percentage of rice drinks substituted for yoghurt increased. Over the course of the whole storage time, the T4 sample had the lowest value and the control sample the highest. Significant differences were observed between the storage days ($p \leq 0.05$). The viscosity values rose in all treatments during the storage period, as can be seen in the table. Stated differently, a decrease in syneresis and an increase in viscosity were required to achieve the hard structure. Bulut *et al*. (2021) provided an explanation for this and stated, that the tightening of the gel structure and an increase in the water-holding capacity of proteins during storage are the causes. The viscosity of samples containing rice milk was shown to be reduced on yoghurts made from rice milk (Uzuner *et al*, 2016).

Yogurt's primary flavouring ingredients are acetaldehyde, acetoin, acetone, and diacetyl of carbonyl compounds. However, acetaldehyde has been linked by numerous studies to yoghurt's desirable flavour (Tamime & Deeth, 1980). The amount of acetaldehyde in milk can be affected by heating it to high temperatures, adding more dry matter, adding milk or milk powder, the type of milk, and the characteristics of the yoghurt bacteria (Niamah *et al*, 2023). Table 4 lists the probiotic yoghurt samples' average acetaldehyde readings. The samples' acetaldehyde concentrations ranged from 13.90 to 28.94 ppm. Acetaldehyde levels dropped as the percentage of rice drinks consumed in place of yoghurt rose. On the 15th day of storage, T4 had the lowest value, while the control sample had the highest value when it was fresh (at 0 day for storage). After storing the samples for 15 days, there was a significant difference between them ($p \leq 0.05$). Since the start of storage, the amount of acetaldehyde has tended to decrease. According to reports, the conversion of acetaldehyde to ethyl alcohol is linked to the drop in acetaldehyde concentrations over the course of storage (Moineau-Jean *et al*, 2020). Yoghurt samples' acetaldehyde concentrations have altered over time. These irregular variations in acetaldehyde during storage could be caused by the mix formulation, culture, and storage circumstances (Niamah *et al*., 2023; Akarca & Denizkara, 2024). The nonstarter lactic acid bacteria may also be connected to the decreased acetaldehyde content. Acetaldehyde levels in samples containing rice milk were observed to be reduced on yoghurts made from rice milk (Uzuner *et al*, 2016).

Table 4. Influence of black rice beverage addition on the Titratable acidity, pH, Viscosity and acetaldehyde values of yoghurt drink during storage at refrigerator temperature for 15 day

Parameters	Storage period (Day)	Treatments				
		C	T_1	T2	T3	T4
Acidity %	0	0.72±0.02^{f}	0.68±0.05^{fg}	0.66±0.03^{fg}	0.64±0.02^{g}	0.62±0.04^{g}
	5	0.84±0.04^{d}	0.76±0.03^{ef}	0.72±0.0^{f}	0.70±0.07^{f}	0.66±0.06^{fg}
	10	0.96±0.05^{b}	0.84±0.02^{d}	0.80±0.04^{e}	0.76±0.08^{ef}	0.72±0.05^{f}
	15	1.12±0.03^{a}	0.95±0.05^{b}	0.90±0.03^{c}	0.82±0.04^{de}	0.78±0.02^{ef}
pH	0	5.04±0. 04^{ab}	5.06±0.06^{ab}	5.06±0.02^{ab}	5.08±0.04^{a}	5.09±0.05^{a}
	5	4.82±0.03^{cd}	4.86±0.04^{c}	4.88±0.05^{c}	4.92±0.04^{bc}	4.96±0.06^{b}
	10	4.24±0.05^{e}	4.25±0.03^{e}	4. 28±0.04^{de}	4.30±0.06^{d}	4.34±0.03^{d}
	15	4.08±0.04^{fg}	4.10±0.06^{fg}	4.13±0.05^{f}	4.16±0.05^{f}	4.20±0.04^{ef}
Viscosity (Pa.s)	0	3.56 ±0.09^{c}	3.42 ±0.08^{d}	3.34±0.09^{e}	3.28±0.11^{ef}	3.22±0.07^{f}
	5	3.72±0.08^{bc}	3.48±0.11^{d}	3.40±0.08^{de}	3.33±0.09^{e}	3.28±0.1e^{f1}
	10	3.77±0.11^{b}	3.55±0.12^{c}	3.46±0.09^{d}	3.38±0.07^{de}	3.34±0.09^{e}
	15	3.86±0.09^{a}	3.60±0.08^{c}	3.52±0.06^{c}	3.45±0.06^{d}	3.40±0.08^{de}
Acetaldehyde (ppm)	0	28.94±0.26^{a}	26.80±0.22^{b}	25.20±0.30^{c}	24.30±0.46^{d}	22.90±0.38^{f}
	5	23.80±0.30^{e}	21.70±0.34^{g}	19.80±0.36^{h}	18.20±0.40^{i}	17.90±0.44^{j}
	10	21.50±0.46^{g}	18.60±0.22^{i}	16.50±0.40^{k}	15.90±0.36^{l}	15.30±0.24^{l}
	15	19.40±0.38^{h}	16.30±0.36^{k}	14.80±0.33^{m}	14.20±0.45^{m}	13.90±0.32^{m}

Means in the same row that are denoted by several little letters differ significantly ($p\leq 0.05$). Each yoghurt sample underwent a triplicate analysis after each experiment was carried out in triplicate. C: yoghurt drink made from cow milk as a control , T1: Yoghurt drink containing 10 % black Rice beverage , T2: Yoghurt drink containing 20 % black Rice beverage, T3: Yoghurt drink containing 30 % black Rice beverage, T4: Yoghurt drink containing 40 % black Rice beverage.

Influence of black rice beverage addition on the phytochemical properties of yoghurt drink

Plant compounds called polyphenols are used to treat and prevent a number of illnesses. Stronger free radical inhibition and significant antioxidant activity are demonstrated by the greater polyphenol content (Yu *et al*., 2021). Antioxidant activity is taken into account, which depends on the test system, substrate that needs to be preserved by the antioxidant, and the purity of active molecules (Atwaa *et al*, 2022). The yoghurt drink products that were produced had a substantial ($p\leq 0.05$) increase in total anthocyanin, total phenolic content, and antioxidant activity when black rice beverage was added to the formula (Table 5). Black rice may have greater amounts of total anthocyanin, total phenolic content, and antioxidant activity, which could account for these results (Fatchiyah *et al*. 2020, Winarti *et al*. 2021: Phanumong & Prommajak, 2023). The total anthocyanin, total phenolic content, and antioxidant activity values of all yoghurt drink treatments dramatically reduced as the storage period extended. Similar findings that the addition of black rice powder or extracts to dairy products greatly boosted their total anthocyanin, total phenolic content, and antioxidant activity were noted (Elkot *et al*. 2022, Ariyani *et al*. 2019: Anuyahong *et a*l. 2020).

Table 5. Influence of black rice beverage addition on the phytochemical properties of yoghurt drink during storage at refrigerator temperature for 15 day

Parameters	Storage period (Day)	Treatments				
		C	T_1	T2	T3	T4
Total phenolic content (mg /100 g)	0	55.20±1.9^{p}	190±2.4^{j}	236±4.3^{h}	382±3.8^{d}	522±5.6^{a}
	5	48.50±1.4^{q}	162±2.7^{l}	204±3.2^{i}	348±4.2^{e}	486±4.86^{a}
	10	40.70±1.6^{r}	124±1.8^{n}	186±2.6^{k}	294±4.5^{f}	432±5.5^{c}
	15	32.60±1.5^{s}	104±2.5^{o}	140±3.4^{m}	242±5.2^{g}	380±3.8^{d}
Radical scavenging activity RSA %	0	17.60±1. 2^{i}	25.20±1.6^{g}	32.70±1.02^{e}	38.60±1.8^{c}	46.50±1.5^{a}
	5	14.50±1. 6^{j}	21.60±1.04^{h}	28.50±1.5^{f}	33.70±1.04^{d}	40.70±1.2^{b}
	10	12.30±1. 3^{k}	17.90±1.06^{i}	22. 20±1.04^{h}	28.50±1. 3^{f}	34.60±1. 5^{d}
	15	9.80±1. 4^{l}	13.70±1.2^{j}	16.50±1.6^{i}	21.40±1.5^{h}	28.50±1. 4^{f}
Total Anthocyanin Content (mg/L)	0	0.00±0.0^{o}	14.20±1.08^{k}	24.50±1.14^{h}	38.60±1.14^{d}	56.30±1.12^{a}
	5	0.00±0.0^{o}	12.50±1.12^{l}	20.80±1.08^{i}	33.20±1.15^{f}	50.00±1.08^{b}
	10	0.00±0.0^{o}	9.30±1.09^{m}	16.40±1.16^{j}	27.00±1.12^{g}	44.80±1.14^{c}
	15	0.00±0.0^{o}	6.40±1.16^{n}	12.70±1.12^{l}	20.50±1.09^{i}	36.70±1.08^{e}

Means in the same row that are denoted by several little letters differ significantly ($p\leq 0.05$). Each yoghurt sample underwent a triplicate analysis after each experiment was carried out in triplicate. C: yoghurt drink made from cow milk as a control , T1: Yoghurt drink containing 10 % black Rice beverage , T2: Yoghurt drink containing 20 % black Rice beverage, T3: Yoghurt drink containing 30 % black Rice beverage, T4: Yoghurt drink containing 40 % black Rice beverage

Influence of black rice beverage addition on the total bacterial and bifidobacteria counts of yoghurt drink

Examining the yoghurt drink's total bacterial and bifidobacteria counts is essential for determining the microbiological quality of the finished product. The average total bacterial and bifidobacteria counts in yoghurt drink treatments are displayed in Table 6. The addition of black rice beverage considerably boosted ($p\leq 0.05$) the total bacterial and bifidobacteria counts. Additionally, up until the fifth day of storage, the overall bacterial and bifidobacteria counts of all treatments grew; after that, they progressively dropped until the conclusion of the storage period. These findings may be the consequence of certain ingredients in black rice beverages that promote the growth of bacteria as prebiotics, particularly oligosaccharides (Pei *et al*., 2023). This, in turn, increases the viability and survival of bifidobacteria in the resulting probiotic fermented camel milk. Moreover, simple sugars included in date syrup promote bacterial development and activity. These outcomes concur with the previous by Elkot *et al*, (2022).

Table 6. Influence of black rice beverage addition on the total bacterial and bifidobacteria counts of yoghurt drink during storage at refrigerator temperature for 15 day

Parameters	Storage period (Day)	Treatments				
		C	T_1	T2	T3	T4
	0	8.03±0.04^{h}	8.05±0.03^{h}	8.08±0.0^{h}	8.06±0.07^{h}	8.04±0.06^{h}
Total bacterial counts (Log cfu/mL)	5	8.22±0.02^{f}	8.36±0.05^{e}	8.44±0.03^{d}	8.62±0.02^{b}	8.70±0.04^{a}
	10	7.74±0.05^{k}	7.92±0.02^{i}	8.02±0.04^{g}	8.24±0.08^{f}	8.52±0.05^{c}
	15	7.56±0.03^{l}	7.84±0.05^{j}	7.90±0.03^{i}	8.12±0.04^{g}	8.40±0.02^{d}
	0	7.60±0.06^{h}	7.66±0.04^{g}	7.65±0.05^{g}	7.66±0.04^{g}	7.68±0.03^{f}
Bifidobacteria counts (Log cfu/mL)	5	7.92±0. 04^{e}	7.98±0.06^{d}	8.14±0.02^{c}	8.32±0.04^{b}	8.66±0.05^{a}
	10	7.64±0.03^{g}	7.70±0.06^{f}	7. 88±0.04^{e}	8.15±0.03^{c}	8.34±0.05^{b}
	15	7.40±0.04^{c}	7.62±0.05^{h}	7.74±0.05^{f}	7.94±0.06^{e}	8.02±0.04^{d}

Means in the same row that are denoted by several little letters differ significantly (p≤ 0.05). Each yoghurt sample underwent a triplicate analysis after each experiment was carried out in triplicate. C: yoghurt drink made from cow milk as a control , T1: Yoghurt drink containing 10 % black Rice beverage , T2: Yoghurt drink containing 20 % black Rice beverage, T3: Yoghurt drink containing 30 % black Rice beverage, T4: Yoghurt drink containing 40 % black Rice beverage

Sensory properties of Yoghurt drink containing black rice beverage:

Table 7 shows the yoghurt drink samples' sensory property values. The yoghurt drink samples' sensory characteristics had appearance values ranging from 3.30 to 4.75. The control sample yielded the highest value after 15 days, while the T4 sample had the lowest value throughout the first storage period. The variations amongst the storage days were statistically significant (p≤ 0.05). T3 and T4 received lower ratings, while C, T1, and T2 had close ones. The samples exhibited the highest appearance grades on the fifteenth day of storage. After a while, protein hydration and gel formation—which affect the appearance—occurred (Rasic & Kurman 1987). In terms of sensory qualities, the yoghurt drink samples' consistency values ranged from 2.80 to 4.80. T2 had the highest value at the 15-day mark, while T4 had the lowest value at the start of the storage period. Between the various storage days, there was a significant difference (p ≤0.05). T3 and T4 received lower ratings, while C, T1, and T2 had close ones. Even if the panellists have received training, a little perception of an aesthetic defect may have led to a low rating. As a result, our consistency values exhibit a wide variation.

Table 7. Sensory properties of Yoghurt drink containing black rice beverage during storage at refrigerator temperature for 15 day

Components (%)	Treatments					
	Storage period (Day)	C	T_1	T2	T3	T4
Appearance	0	4.60±0. 2^{a}	4.30±0. 5^{ab}	4.10±0. 3^{b}	3.70±0. 2^{bc}	3.30±0. 6^{c}
	5	4.65±0. 5^{a}	4.40±0. 4^{ab}	4.20±0. 1^{b}	3.75±0. 4^{b}	3.35±0. 4^{c}
	10	4.70±0. 3^{a}	4.50±0. 5^{ab}	4.30±0. 4^{ab}	3.80±0. 5^{b}	3.40±0. 2^{c}
	15	4.75±0. 1^{a}	4.55±0. 3^{ab}	4.35±0. 5^{ab}	3.85±0. 04^{b}	3.45±0. 7^{k}
Consistency	0	4.30±0. 5^{ab}	4.00±0. 6^{b}	3.70±0. 3^{c}	3.20±0. 3de	2.80±0. 1^{ef}
	5	4.40±0. 4^{ab}	4.20±0. 5^{b}	3.80±0. 4^{bc}	3.25±0. 6de	2.90±0. 5^{e}
	10	4.60±0. 2^{a}	4.40±0. 4^{ab}	3.95±0. 2^{bc}	3.30±0. 2^{d}	3.00±0. 3^{e}
	15	4.80±0. 3^{a}	4.50±0. 3^{ab}	4.00±0. 3^{b}	3.35±0. 4^{d}	3.05±0. 2^{e}
Odour	0	4.60±0. 5^{a}	4.20±0. 4^{b}	3.80±0. 4^{bc}	3.30±0. 3^{cd}	2.90±0. 6de
	5	4.70±0. 4^{a}	4.40±0. 5^{ab}	4.00±0. 6^{b}	3.40±0. 5^{c}	3.10±0. 4^{d}
	10	4.75±0. 6^{a}	4.45±0. 6^{ab}	4.10±0. 5^{b}	3.45±0. 4^{c}	3.20±0. 5^{d}
	15	4.65±0. 2^{a}	4.50±0. 3^{ab}	3.90±0. 5^{b}	3.35±0. 3^{c}	3.00±0. 2^{d}
Flavor	0	4.40±0. 3^{ab}	4.20±0. 1^{ab}	4.10±0. 4^{b}	4.00±0. 5^{b}	3.80±0. 7^{b}
	5	4.60±0. 5^{a}	4.40±0. 5^{ab}	4.30±0. 6^{ab}	4.20±0. 6^{ab}	4.00±0. 3^{b}
	10	4.70±0. 3^{a}	4.50±0. 4^{a}	4.40±0. 5^{ab}	4.30±0. 3^{ab}	4.20±0. 4^{ab}
	15	4.80±0. 4^{a}	4.60±0. 2^{a}	4.50±0. 3^{ab}	4.40±0. 4^{ab}	4.20±0. 2^{ab}
General Evaluation	0	4.47±0. 2^{c}	4.17±0. 1^{d}	3.92±0. 1de	3.55±0. 2^{ef}	3.20±0. 2^{g}
	5	4.58±0. 1^{bc}	4.35±0. 1^{cd}	4.07±0. 2^{d}	3.65±0. 1^{e}	3.33±0. 1^{fg}
	10	4.68±0. 2^{b}	4.46±0. 2^{c}	4.18±0. 1^{d}	3.71±0. 2^{e}	3.45±0. 3^{f}
	15	4.75±0. 3^{a}	4.53±0. 3^{bc}	4.18±0. 2^{d}	3.73±0. 3^{e}	3.42±0. 2^{f}

Means in the same row that are denoted by several little letters differ significantly (p≤ 0.05). Each yoghurt sample underwent a triplicate analysis after each experiment was carried out in triplicate. C: yoghurt drink made from cow milk as a control , T1: Yoghurt drink containing 10 % black Rice beverage , T2: Yoghurt drink containing 20 % black Rice beverage, T3: Yoghurt drink containing 30 % black Rice beverage, T4: Yoghurt drink containing 40 % black Rice beverage.

The sensory qualities of the yoghurt drink samples showed odour ratings ranging from 2.90 to 4.75. The control sample had the highest value at 10 days, whereas the T4 sample had the lowest value at 0 day for storage. A significant change (p≤0.05) was observed between the storage days. The yoghurt drink samples' flavour scores for sensory attributes ranged from 3.80 to 4.80. The control sample had the highest value at 10 and 15 days, while the T4 sample had the lowest value at 0 day for storage. Significant differences were observed between the storage days (p≤0.05). By computing the average values of each sensory parameter of the samples, a general evaluation was obtained. The samples of yoghurt drinks received general sensory property scores ranging from 3.20 to 4.75. The control sample had the highest value at 15 days, while the T4 sample had the lowest value at 0 day foe storage. A significant change (p≤0.05) was observed between the storage days.

The control group got the most points out of all the groups, and the samples that had black rice beverage added to them decreased in inverse proportion to the amount of black rice beverage. The black rice beverage's sweet flavour and inability to give yoghurt the right consistency and look are the reasons samples containing it scored worse (particularly T3 and T4). In samples with lesser black rice beverage contents (T3 and T4), this sweet flavour is detectable to a minor extent, but in samples with higher black rice beverage content (T4), it is strongly felt. These outcomes concur with the findings of Uzuner *et al*. (2016).

CONCLUSION

The dairy sector is concentrating on creating innovative production techniques or aggressive marketing plans to satisfy consumers' diverse tastes and health-related demands while also raising the per-capita consumption of dairy products. The process of turning black rice liquor into food products is still in its infancy, and researchers are looking into how it may affect human health. The purpose of this study was to introduce a new fermented dairy product to the dairy industry, educate the public about its nutritional and medicinal properties, provide consumers with an option for a healthy diet, and raise per capita consumption. We also thought that our findings might serve as a reference for future research and the selection of starting cultures for projects of a similar nature. Samples containing black rice beverages generally produced acceptable results. Nonetheless, because they were the most similar to the control group among the samples with black rice beverage, T1 and T2 samples were the most well-liked products. The consumption of such items is continuously expanding as the customers' tendency to perceive them as functional products rather than traditional food products increase.

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إنتاج مشروب زبادي وظيفي غني بمشروب الأرز الأسود

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الملخص

هناك دراسات سابقة ركزت على إنتاج مشروب الزبادي الحيوي المصنع باستخدام مواد خام نباتية مثل الشوفان والصويا ، ولكن هناك عدد محدود من الدراسات حول استخدام مشروب الأرز الأسود في منتجات الألبان المتخمرة. في هذه الدراسة , تم إنتاج أربعة أنواع مختلفة من عينات مشروب الزبادي: حيث تم استبدال زبادي اللبن البقري بـ 10، 20، 30 و 40٪ من مشروب الأرز الأسود في تركيبة مشروب الزبادي، على التوالي) وتخزينها لمدة 15 يومًا عند درجة حرارة 4 درجات مئوية. تم تقدير الخصائص الفيزيائية والكيميائية والفيتوكيميائية والميكروبيولوجية والحسية للعينات وهي طازجة وعند مرور 5 و 10 و 15 يومًا من التخزين. تبين أن إضافة مشروب الأرز الأسود إلى تركيبة مشروب الزبادي أدى إلى زيادة معنوية في قيم المواد الصلبة الكلية ,البروتين ,الأنثوسيانين .الفينولات , نشاط مضادات الأكسدة , درجة ال pH واللزوجة ولكن انخفض قيم الحموضة ,الدهن , الرماد والأسيتالدهيد في مشروب الزبادي. كما أدت إضافة مشروب الأرز الأسود إلى زيادة إجمالي أعداد البكتيريا الكلية وبكتيريا البيفيدوبكتريا. في التحليل الحسي، انخفضت الدرجات مع زيادة نسب مشروب الأرز الأسود في تركيبة مشروب الزبادي، وأفاد أعضاء اللجنة بأن عينات T1 وT2 (والتي استبدل فيها زبادي اللبن البقري بـ 10 و20% من مشروب الأرز الأسود في تركيبة مشروب الزبادي، على التوالي) كانت العينة الأقرب لعينة المقارنة (مشروب زبادي من لبن بقري 100%). ويتزايد استهلاك هذه المنتجات بشكل مستمر مع تزايد ميل المستهلكين إلى اعتبارها منتجات وظيفية بدلاً من المنتجات الغذائية التقليدية.