

# Effect of *Njavara* rice bran on physico-chemical, sensory, and textural properties of sweetened yoghurt

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**Abstract:** *Njavara* rice and rice bran possess numerous therapeutic applications, including their utilization in alleviating diabetes, cervical spondylitis, rheumatoid arthritis, neuromuscular diseases, psoriasis, skin lesions, and stomach ulcers. In recent decades, numerous studies have shown increasing attention towards functional foods which is positively associated with better nutritional status and quality of life, and the decreased incidence of noncommunicable diseases. This can be attributed to the growing awareness among consumers regarding the correlation between nutrition and health, leading to an increased emphasis on personal well-being. Therefore, to improve the health properties of sweetened yogurt containing 10% cane sugar, *Njavara* rice bran was added in amounts ranging from 0% to 10%. The impact of these additions on the quality of the product, specifically in terms of physicochemical properties, sensory qualities, and texture, was evaluated. A standard method was followed for the preparation of rice bran-fortified sweetened yoghurt. The addition of rice bran was found to have a significant impact on the physico-chemical characteristics of sweetened yoghurt. An increase in rice bran was associated with a decrease in yoghurt's titratable acidity. Conversely, the yoghurt's syneresis, water activity, and antioxidant activity were found to increase. Furthermore, the inclusion of rice bran in the yoghurt formulation resulted in a reduction in  $L^*$  and an increase in  $a^*$  values. The addition of increasing quantities of rice bran (7%

and 10%) was found to have a negative impact on the sensory and textural properties of the yoghurt. Based on the results it can be concluded that fortification of sweetened yoghurt with 5% rice bran could produce a functional product with healthy properties besides its valuable nutritive value.

**Keywords:** *Njavara*, Rice bran, Yoghurt, Functional foods, Fermented foods

## Introduction

The science of nutrition is shifting its focus from defining daily dietary guidelines to gaining knowledge of nutrient functions and metabolism, promoting health, and mitigating illness risk through consumption. Functional food science is a subfield of nutrition science that seeks to enhance dietary requirements by incorporating new knowledge regarding the relationships between food ingredients and physiological processes. Functional foods are industrially processed or naturally occurring foods that, when regularly consumed as part of a varied diet at adequate levels, may offer health benefits beyond essential nutrition (Granato et al. 2020). The modern trend in developing functional foods is to enhance the health benefits of commonly consumed foods by adding functional components such as phytochemicals, prebiotics, probiotics, dietary fiber, vitamins, minerals, etc. Looking at the importance of functional foods, FSSAI came out with Food Safety and Standards (Food or Health Supplements, Nutraceuticals, Foods for Special Dietary Uses, Foods for Special Medical Purposes, Functional Foods, and Novel Food) Regulations, 2016. The global functional foods market size was estimated at USD 304.2 billion in 2022 and is expected to expand at a compound annual growth rate (CAGR) of 8.5% from 2022 to 2030, projected to reach USD 586.1 billion in 2030 (Grand View Research (n.d.)).

Humans have consumed fermented foods for several years. Although they were most likely intended for preservation, it would have been evident that these foods had other desirable qualities. Fermented foods have distinct aromas, body and textures, and functions compared to the raw components from which they are prepared (Tamang et al. 2020). Yoghurt is a popular dairy product made by the bacterial fermentation of milk

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which involves thermophilic strains of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* ssp. *bulgaricus*. Fermented dairy products are recognized for their exceptional nutritional and health-related characteristics, such as their ability to exhibit antimutagenic properties and prevent lower serum cholesterol levels and gastrointestinal infections. These are advantageous for consumption by individuals who are lactose intolerant and those who have atherosclerosis (Rasane et al. 2017). Yoghurt is a rich source of calcium in its bio-available form. It is also a good source of potassium, phosphorous, vitamin A, and vitamin B, especially vitamin B2, and vitamin B12. It also provides essential fatty acids and valuable proteins (Hadjimbei et al. 2022).

The *Oryza sativa* ssp. *indica* variety Njavara (GI Kerala, India 2007) is an early maturing (60–70 days) red rice variety with medicinal properties (Solanki et al. 2019). Njavara rice is slightly sweet and it is considered a magical rice which boosts immunity. Its bran is rich in fiber and is beneficial for all people who are suffering from digestion problems. Also, it is rich in bioactive compounds, especially phenolic and phytochemical compounds, which are excellent antioxidants (Nayeem et al. 2021). Njavara rice and rice bran are used to treat diabetes, cervical spondylitis, rheumatoid arthritis, neuromuscular disorders, psoriasis, skin lesions, and stomach ulcers (Kowsalya et al. 2022). It is also recommended in the preparation of weaning food for underweight babies. Broth made by adding Njavara rice is recommended to pregnant women as it increases the weight of the foetus. Cooked with milk and herbs, it can treat internal wounds (Rathna-Priya et al. 2019). Red and black rice grains have the maximum concentration of phenolic and anthocyanin compounds compared to other rice grains (Haskito et al. 2020). Rice bran contains a diverse array of phytochemicals, such as phytic acid, ferulic acid, tocotrienols,  $\gamma$ -oryzanol, flavonoids, and phytosterols which makes them excellent antioxidants (Law et al. 2017). With the provision of using rice bran as a nutraceutical as per Food Safety and Standards (Health Supplements-Nutraceuticals) Regulations (2022), there is a scope for new dairy product (functional food) development. In view of the above, the present investigation was carried out to develop Njavara rice bran-fortified sweetened yoghurt and to study the effect of red rice bran on the physicochemical, sensory, and textural attributes of yoghurt.

## Materials and methods

### Materials

The buffalo milk used in the study was sourced from the Experimental Dairy of ICAR-National Dairy Research Institute (NDRI), Karnal. Starter culture NCDC-263 containing *Streptococcus thermophilus* and *Lactobacillus bulgaricus* was obtained from the National Collection of Dairy Cultures (NCDC) at ICAR-National Dairy Research Institute (NDRI), Karnal (India).

The starter culture was maintained in autoclaved reconstituted skimmed milk (12g/100mL) by sub-culturing once a fortnight to attain high activity. The Njavara rice bran used in the study was purchased directly from a farmer in Kerala (details can be provided on request). Skim milk powder (Brand: Dairy Best) manufactured by M/s Pashupati Dairies Pvt. Ltd., Dehradun was procured from the local market. Polystyrene (PS) cups with lids (aluminum) of 100 mL capacity were procured from M/s Rajlaxmi Trading and Manufacturing Co., Karnal, and used for the packaging of the product.

### Preparation of Rice Bran fortified Yoghurt

For preparing Njavara rice bran-fortified sweetened yoghurt, the fresh raw buffalo milk was standardized to 3% fat and 8.5% solids-not-fat (SNF) using fresh raw buffalo milk and skimmed milk powder (SMP), respectively and 10% sugar was added. Then the milk was subjected to two-stage homogenization (2000/500 psi) after heating to 60°C. Further, rice bran was added to the homogenized milk at different levels (0%, 1%, 3%, 5%, 7%, 10%) and subjected to high shear mixing. Then it was heat treated at 90°C for 15 min and then cooled to 45°C. The starter culture was added at 1% and filled into pre-sterilized 100 mL cups. Incubation was carried out at 45°C for about 5-6 hours till a final titratable acidity of 0.6% expressed as lactic acid was reached. Once the desired acidity was obtained, without disturbing the set product, cups were transferred to refrigerator storage. All the trials were carried out in triplicate.

### Physico-chemical analysis

#### Titratable acidity

The AOAC (2005) method was used to determine the titratable acidity. A yoghurt sample of around 10 g was weighed in a conical flask and diluted with double-distilled water to twice its volume. After adding two mL of phenolphthalein indicator, the mixture was titrated with 0.1 N NaOH until a persistent pink colour developed. The following formula was used to determine acidity, which was expressed as % lactic acid by weight.

$$\text{Acidity (\% LA)} = \frac{9NV_1}{V_2}$$

Where N = The normality of the NaOH used,  $V_1$  = The volume (mL) of the sample used for the test, and  $V_2$  = The volume (mL) of 0.1 N NaOH required for the titration.

#### Water activity

The water activity of rice bran fortified sweetened yoghurt was measured using the water activity meter "Aqua Lab" (Model series 3 TE) supplied by Decagon Devices, WA, USA. Prior to measurement, the samples were tempered to 25°C.

### pH

The pH of the samples was measured using a digital pH meter (EUTECH Instruments, Singapore) at 20°C using a combined glass electrode fitted in association with a temperature probe. Before use, the pH meter was calibrated using standard buffers of pH 4.0 and 9.0 at 20°C. The pH values were measured in duplicate at three different times to monitor the fermentation.

### Antioxidant activity (DPPH)

With a few minor adjustments, the method described by (Brand-Williams et al. 1995) was used to test the DPPH (2,2-diphenyl-1-picrylhydrazyl) free radical scavenging activity. 1 g sample was diluted in 25 ml of 60% methanol. Further, 2.9 ml of 60 mM DPPH in methanol was added to 100 µL of the diluted sample and kept in the darkness for 30 min. The absorbance of the reaction mixture was then measured at 517 nm. As a blank, methanol was utilized. Triplicate measurements were taken. DPPH radical scavenging capacity was calculated by using the following formula:

$$\text{Radical Scavenging Activity (\%)} = \frac{(\text{Absorbance}_{\text{blank}} - \text{Absorbance}_{\text{sample}}) \times 100}{\text{Absorbance}_{\text{blank}}}$$

### Syneresis

After taking it out of the refrigerator, a cup of yoghurt was stirred 20 times in a clockwise and counterclockwise direction. Using a 5 mL pipette, about 30 g of the sample was placed into a 50 mL polypropylene conical centrifuge tube and stabilized for 2 hours at 5 °C. To observe whey separation, the agitated samples were centrifuged at 3000 rpm for 15 minutes at 10 °C. Syneresis was expressed as percent syneresis (Hussain et al. 2016).

$$\text{Percent syneresis} = \frac{\text{Weight of separated whey}}{\text{Initial weight of sample}} \times 100$$

### Colour analysis

The surface colour of yoghurt was measured using a “Colourflex” colorimeter and software (version 4.10) supplied by Hunterlab (Hunter Associates Laboratory, Inc., Reston, VA, USA), and the results were expressed using the CIELAB system. 75 mL of the pasteurized and cooled yoghurt mixture was poured into a sterilized glass beaker with a diameter of 10 cm and a height of 6 cm, and incubation was performed. After approximately 16 hours of storage at 6-8°C, the cups were removed from the refrigerator and tempered at 25°C for 2 hours. Then, using a spatula, the

contents of the beakers were loosened from the sides and transferred to the sample container attached to the Colourflex device. For each sample, measurements were taken in triplicate (Raju and Pal, 2011).

### Texture measurement

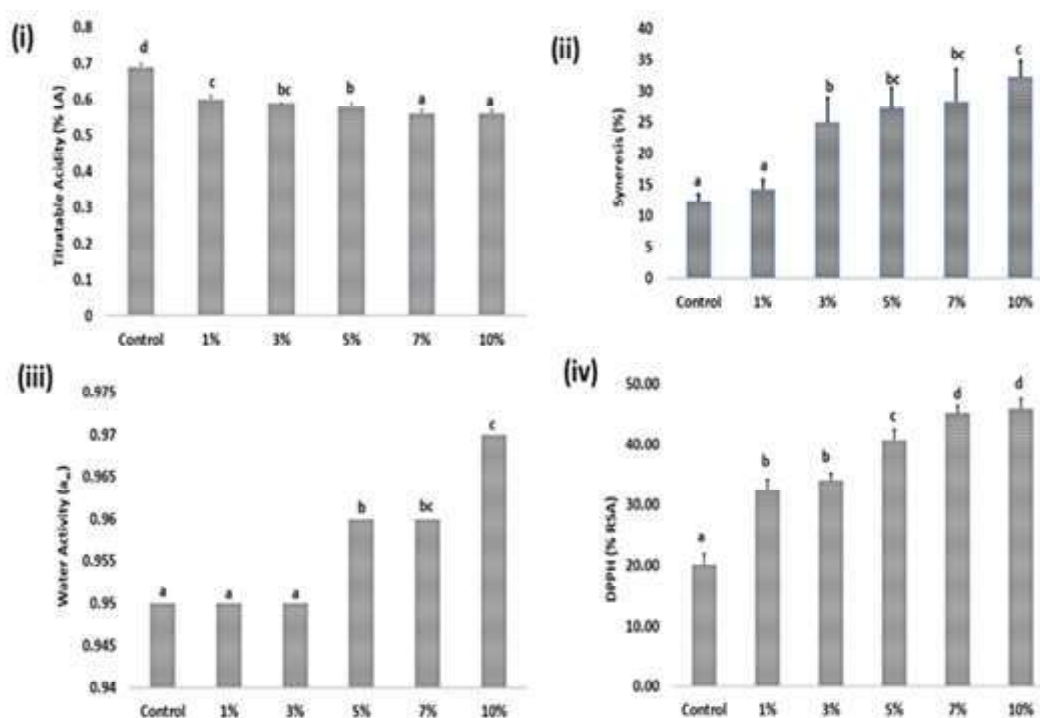
Using the texture analyzer, TA-XT plus (M/s Stable Micro Systems, UK), equipped with a 50 kg load cell and back extrusion method the textural properties were determined. For determining the textural attributes, inoculated milk was filled (~140 mL) up to 5 cm in a sterilized glass tumbler (10 cm height and 6 cm diameter), and incubation was carried out in the tumblers itself. Before analysis, the beakers were tempered at 25°C for 2 h. The back extrusion probe (A/BE) with a 5 cm diameter disc and extension bar was used. The extrusion disc was positioned centrally over the sample container. At a crosshead speed of 1.0 mm/s, it penetrated 10 mm (20% compression) into the yoghurt. Through compression and back extrusion, the probe moved the material, which caused the fluid to rise through the annular space. From the resulting force-time curves, firmness, i.e., the ‘peak’ or maximum force (g), consistency, i.e., the area under positive region (g.sec), cohesiveness (g), i.e., maximum negative force, and work of cohesion (g.sec), the area of the negative region of the curve were calculated using the instrument attached software (Exponent Connect™). All measurements were done in triplicate for each sample.

### Sensory analysis

The sensory evaluation of the yoghurt samples was done using a 9-point Hedonic scale. The specimens were instantly removed from the refrigerator before being presented to the evaluators. A sensory review panel of five judges was chosen from the Dairy Technology Division of ICAR-NDRI, Karnal, who were well-versed in sensory evaluation procedures and product qualities. The sensory qualities of yoghurt were evaluated in the study, including colour and appearance, flavour, body and texture, and overall acceptance. The sensory evaluation tool used a nine-category hedonic grading system: dislike excessively (1), dislike very much (2), dislike moderately (3), dislike slightly (4), neither like nor dislike (5), like slightly (6), like moderately (7), like very much (8), and dislike severely (9) (Hussain et al. 2016).

### Statistical analysis

Data obtained from various experiments were recorded as mean ± standard deviation (SD) and subjected to statistical analysis. Triplicate samples with triplicate measurements from each group (n = 3) were taken to estimate the physico-chemical, sensory, and textural properties of each of the different treatments for consistency of the results. Data were analyzed using one-way analysis of variance (ANOVA) at a 5% level of significance. The mean values were compared using Duncan’s paired comparison test using SPSS software (version 26, M/s IBM corporation).



**Fig. 1** Effect of *Njavara* rice bran on the physico-chemical properties of sweetened yoghurt: (i) acidity; (ii) syneresis; (iii) water activity; and (iv) antioxidant activity (DPPH, % Radical scavenging activity). Each observation is a mean  $\pm$  SD of three replicates ( $n=3$ ). <sup>abcd</sup> means values of treatments within a graph with different letters significantly differ ( $P \leq 0.05$ )

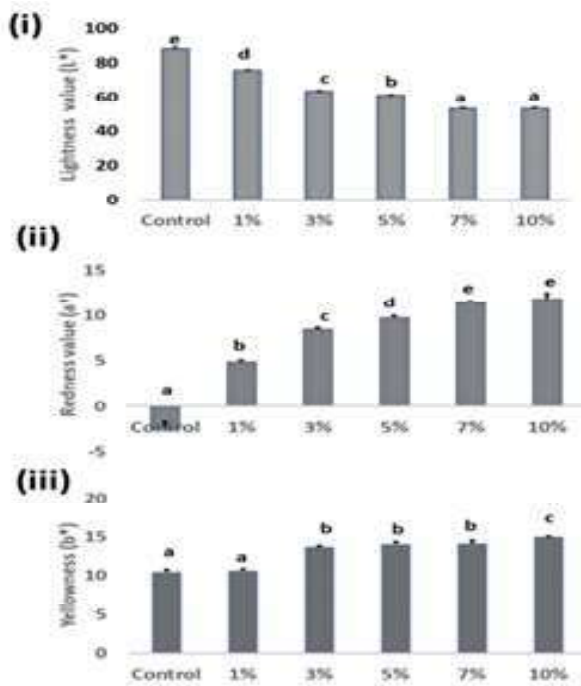
## Results and Discussion

### Effect of *Njavara* rice bran on the physico-chemical properties of sweetened yoghurt

The effect of the incorporation of *Njavara* rice bran on the physicochemical characteristics of sweetened yoghurt is given in Figure 1 and Figure 2. It can be observed that rice bran incorporation significantly ( $P < 0.05$ ) affected most of the physico-chemical properties. Incorporating rice bran into the yoghurt resulted in a significant reduction ( $P < 0.05$ ) in acidity. The acidity of the control yoghurt was found to be significantly higher ( $P < 0.05$ ) compared to the samples containing rice bran. A significant reduction ( $P < 0.05$ ) in the titratable acidity of the yoghurt samples was seen with an increase in the quantity of rice bran. The yoghurt sample that did not contain any bran had the greatest acidity level, measuring at 0.69% lactic acid. This was followed by a 0.6% acidity level in the yoghurt sample with 1% bran addition and a 0.58% acidity level in the yoghurt sample with 5% bran addition. The lowest acidity level of 0.56% was seen in the yoghurt samples with 7% and 10% bran concentrations. The incorporation of fibre into yoghurt resulted in a decrease in the acidity levels of the product, potentially due to the dilution impact. In their study, Issar et al. (2016) observed a consistent reduction in titratable acidity as the proportion of apple pomace fibre in yoghurt increased. In contrast, Hasani et

al. (2017) observed an elevation in the titratable acidity of the yoghurt after the incorporation of wheat bran. Raju and Pal (2014) also reported an increase in the titratable acidity of *misti dahi* following the addition of inulin and attributed this to the soluble fiber characteristic of inulin that might have easily digested by the bacteria and resulted in the formation of organic acids.

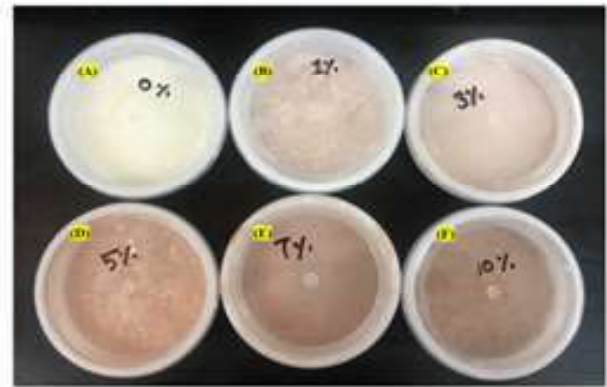
Rice bran addition significantly increased the syneresis ( $P < 0.05$ ) of the sweetened yoghurt compared to the control (Figure 1). The percentage of syneresis seen in the control yoghurt was 12.33%. The addition of rice bran at a concentration of 1.0% resulted in a modest increase in syneresis, although this difference was not statistically significant ( $P > 0.05$ ) when compared to the control yoghurt. It was hypothesized that the inclusion of dietary fibres found in rice bran, such as  $\beta$ -glucan, pectin, hemicellulose, and arabinogalactan, could potentially enhance the water retention properties of yoghurt, thereby reducing the occurrence of syneresis in yoghurt. However, in the current investigation, conversely, elevated quantities of rice bran exhibited a significant increase ( $P \leq 0.05$ ) in the syneresis of the yoghurt samples. The observed increase in yoghurt syneresis after the incorporation of rice bran may be attributed to the potential impact of lactic acid bacteria fermentation on the integrity of the crystalline arrangement and the monosaccharide content of the dietary fibre present in rice bran (Wu et al. 2023).



**Fig. 2** Effect of *Njavara* rice bran on the colour (CIELAB) of sweetened yoghurt: (i) lightness ( $L^*$ ); (ii) redness ( $a^*$ ); and (iii) yellowness ( $b^*$ ). Each observation is a mean  $\pm$  SD of three replicates ( $n=3$ ). <sup>abcde</sup> means values of treatments within a graph with different letters significantly differ ( $P \leq 0.05$ )

Raju and Pal (2014) observed a comparable rise in the whey separation of *misti dahi* after the incorporation of dietary fibres. The slight enhancement in syneresis seen in *misti dahi* containing inulin may be attributed to the disruption of the gel structure, resulting in the separation of whey. In a similar vein, Garcia-Perez et al. (2005) observed that the inclusion of orange fibre at concentrations of 0.6% and 0.8% resulted in a disruptive impact on the gel matrix of yogurt, ultimately leading to an augmentation in syneresis. Demirci et al. (2017) showed that an increase in the content of rice bran resulted in a reduction in the syneresis of yoghurt.

Water activity significantly increased ( $P < 0.05$ ) with rice bran addition to the sweetened yoghurt. Yoghurt with 10% rice bran recorded the highest water activity among all the batches. Measuring water activity provides a more accurate assessment of water's capacity to serve as a reactant and a solvent (Labuza et al. 2020). The increased syneresis seen in bran-fortified yoghurt samples (Figure 1), characterized by the expulsion of water from the gel matrix, can be attributed to the higher water activity resulting from the presence and interaction of bran fibres. Wu et al. (2023) also observed an increase in the syneresis of yoghurt when 2% rice bran was added after fermentation. They attributed this to the change in the monosaccharide composition and damage of the ordered crystal structure of rice bran during the fermentation by lactic acid bacteria.

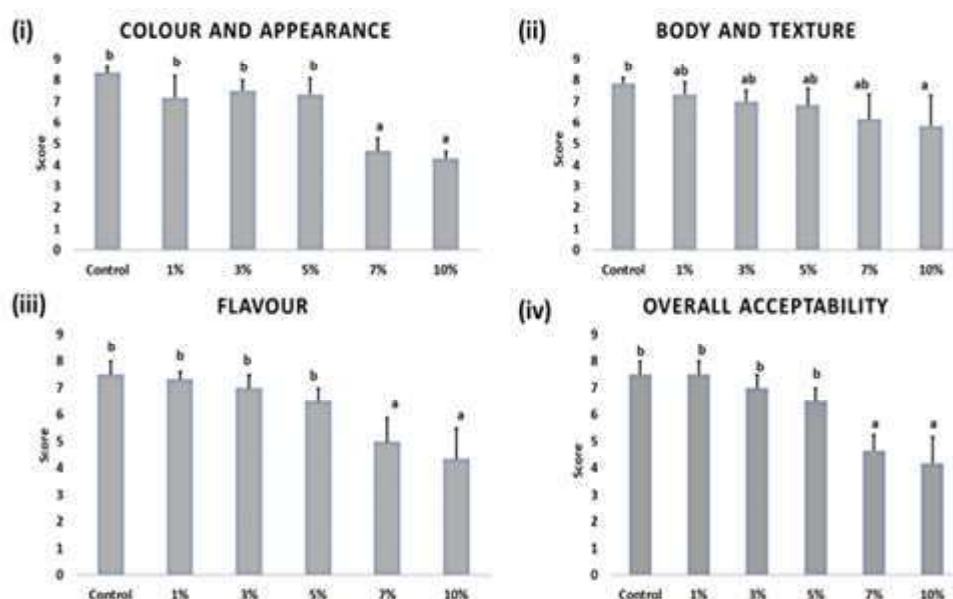


**Fig. 3** Picture of yoghurt added with different levels of *Njavara* rice bran: (A) Control yoghurt (0% bran); (B) yoghurt with 1% bran; (C) yoghurt with 3% bran; (D) yoghurt with 5% bran; (E) yoghurt with 7% bran; and (F) yoghurt with 10% bran

The present study assessed the impact of fortifying sweetened yoghurt with *Njavara* rice bran on its antioxidant activity, as depicted in Figure 1. The data demonstrate a positive correlation between the concentration of rice bran and the DPPH antioxidant activity, specifically in percentage radical scavenging activity. As the level of rice bran increased, the antioxidant activity increased significantly ( $P < 0.05$ ). Including rice bran at a concentration of 1% resulted in a 1.6-fold increase in DPPH activity. Similarly, adding 5% and 10% rice bran increased DPPH activity by 2.03 and 2.28-fold, respectively. Rice bran possesses a substantial quantity of inherent antioxidants that have the potential to function as scavengers of free radicals (Rao et al. 2010). According to a study conducted by Mohanlal et al. (2012), it was found that the red rice variety has a superior radical scavenging function compared to conventional (white) rice kinds. This study shows that incorporating natural compounds, such as red rice bran, can potentially enhance antioxidant activity. Consequently, these food sources can serve as a valuable means for consumers to defend against diseases resulting from the harmful effects of free radicals and oxidative stress. According to Haskito et al. (2020), including red rice bran and black rice bran in goat milk yoghurt increased its antioxidant activity.

The colour of dairy products significantly determines customer acceptability and can exhibit variations in pigment concentration in yoghurt during storage. Adding rice bran led to significant changes in the instrumental colour of sweetened yoghurt. The findings depicted in Figure 2 illustrate a statistically significant reduction ( $P \leq 0.05$ ) in the lightness ( $L^*$ ) measurements of yoghurt upon the incorporation of rice bran in comparison to the control group. The yoghurt samples containing rice bran had a reddish colour (Figure 3). The study observed a significant increase in the  $a^*$  values of rice bran-fortified yoghurt ( $P \leq 0.05$ ), although the impact on the  $b^*$  value was not as pronounced. The  $a^*$  and

**Fig. 4** Effect of *Njavara* rice bran on the sensory properties of sweetened yoghurt: (i) colour and appearance; (ii) body and texture; (iii) flavour; and (iv) overall acceptability. Each observation is a mean  $\pm$  SD of five replicates ( $n=5$ ). <sup>ab</sup> means values of treatments within a graph with different letters significantly differ ( $P\leq 0.05$ )



$b^*$  values of yoghurt supplemented with rice bran varied from 4.93 to 11.87 and 10.62 to 14.94, respectively. In comparison, the control  $a^*$  and  $b^*$  values of control yoghurt were determined to be -2.63 and 10.45, respectively. Similar to the current findings Nontasan et al. (2012) documented a decrease in the lightness measurements of yoghurt following the incorporation of black rice extract. Similarly, Aktas and Akin (2020) observed a decrease in the lightness value of *tarhana* when corn bran was used. The authors also documented a decrease in the  $a^*$  and  $b^*$  values when rice bran and corn bran were used in *tarhana*, contradicting our findings. Similarly, the study conducted by Amjad et al. (2021) documented a notable elevation in the  $L^*$  and  $b^*$  parameters of yoghurt after the incorporation of barley bran. The observed decrease in the  $L^*$  value and increase in the  $a^*$  value of the yoghurt containing rice bran can be attributed to the presence of phenolic compounds inherent in the rice bran, contributing to its distinctive colouration. Additionally, the Maillard browning reaction during heat application, particularly in a substantial quantity of added sugar, may have further influenced these colour changes.

#### Effect of *Njavara* rice bran on the sensory properties of sweetened yoghurt

The sensory qualities of sweetened yoghurt were evaluated concerning the influence of red rice bran, as depicted in Figure 4. There were notable variations seen in the sensory attributes of sweetened yoghurt, with a significant difference ( $P\leq 0.05$ ), except for body and texture, which did not display a significant difference ( $P>0.05$ ). The experimental findings suggest that the control yoghurt demonstrated significantly superior ratings ( $P\leq 0.05$ ) regarding colour and appearance compared to the yoghurt samples with rice bran. The samples with larger concentrations

of rice bran (7% and 10%) received notably lower scores from the panelists. This was attributed to observing a discernible layer of settled rice bran in all cups. The observed combination of higher syneresis in rice bran-supplemented samples (Figure 1) may be responsible for the comparatively lower colour and appearance score of yoghurt containing rice bran. According to Hasani et al. (2017), using barley bran in yoghurt formulation considerably reduced the appearance score. Similarly, the study conducted by Samilyk et al. (2021) revealed that including rice bran in fermented milk had a notable impact on sensory characteristics. Raju and Pal (2014) observed that using oat fiber in *misti dahi* resulted in a notable decrease in colour and appearance evaluations.

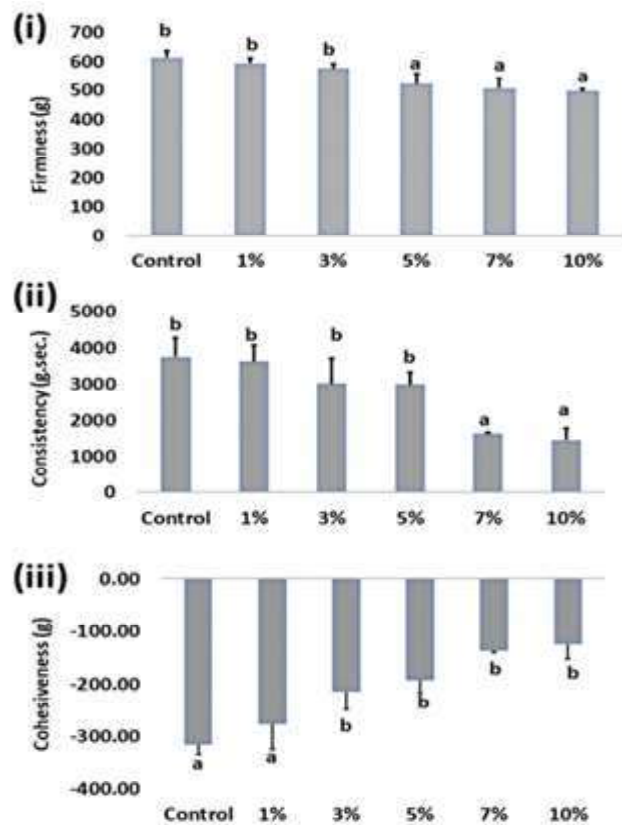
Among the rice bran-fortified samples, the yoghurt fortified with 10% rice bran attained the lowest body and texture scores, with a significant difference ( $P<0.05$ ) from that of the control. Although the other levels of rice bran fortification reduced the body and texture scores, however, they were comparable to the control ( $P>0.05$ ) (Figure 4). The findings on the reduced body and texture scores of sweetened yoghurt supplemented with bran align with the outcomes seen in a study conducted by Samilyk et al. (2021) on yoghurt fortified with rice bran. According to their findings, incorporating rice bran into the formulation led to the separation of whey, leading to an inconsistent body and texture of the product and ultimately decreasing its body and texture scores and overall acceptability. The observed decrease in the body and texture scores of rice bran-supplemented yoghurt may be attributable to the interactions between the fiber and milk solids, resulting in a weakened gel formation. The findings regarding the instrumental firmness and consistency of rice bran-enriched yoghurt, as presented in the section on textural qualities, validate this assertion.

Overall, the addition of bran to sweetened yoghurt resulted in a decrease in flavour scores. However, a statistically significant difference ( $P < 0.05$ ) was only found for the samples fortified with 7% and 10% levels of bran. Previous research has documented similar results. A study conducted by Demirci et al. (2017) showed that the inclusion of rice bran in fermented milk resulted in decreased flavour values compared to plain samples. Furthermore, as the amount of rice bran increased, the acceptability of the samples decreased. According to Raju and Pal (2014), the inclusion of fiber in *misti dahi* substantially impacted the flavour ratings. According to Asadzadeh et al. (2020), there was a substantial decline in flavour scores as the concentration of oat bran extract increased.

Adding rice bran resulted in a substantial decrease in the overall acceptability of sweetened yoghurt compared to the control group ( $P \leq 0.05$ ). Among the batches tested, samples containing 7% and 10% rice bran exhibited the lowest acceptability scores, with statistical significance ( $P < 0.05$ ). Although the acceptance scores of yoghurt with 1%, 3%, and 5% rice bran added were lower than the control group, the observed difference was not statistically significant ( $P > 0.05$ ). The diminished overall acceptability ratings of rice bran-enriched samples may also be ascribed to subpar visual appeal and heightened syneresis, as depicted in Figure 1. The current investigation showed that yoghurt containing rice bran exhibited lower scores than the control group. However, the average scores of yoghurt samples containing 1%, 3%, and 5% rice bran were found to be above 6.5. This suggests that it is possible to produce yoghurt of satisfactory quality by incorporating a maximum of 5% red rice bran. Previous research has yielded comparable results. According to Fernandez-Garcia and McGregor (1997), the augmentation of fibre quantities resulted in enhanced consistency and texture of yoghurt, but at the expense of a decline in its overall sensory quality. In a study conducted by Zomorodi et al. (2015), it was observed that adding wheat bran and apple fibre to probiotic yoghurt decreased sensory scores. A study conducted by Hashim et al. (2009) showed that the inclusion of 4.5% date fibre in yoghurt resulted in a significant fall in the sensory scores of the product.

**Effect of *Njavara* rice bran on the textural properties of sweetened yoghurt**

The impact of including red rice bran on the texture of sweetened yoghurt is illustrated in Figure 4. The addition of bran to yoghurt had a significant impact on its firmness ( $P \leq 0.05$ ). Among all the samples fortified with bran, those containing 7% and 10% levels of bran exhibited the lowest firmness values. The observed reduction in hardness values of sweetened yoghurt may be attributable to the disruptive influence of bran fibres on the gel structure. In a study conducted by Wu et al. (2023), it was observed that the inclusion of rice bran reduced the firmness of yoghurt. Furthermore, the researchers found a positive correlation between the bran concentration and the extent of this impact. The yoghurt



**Fig. 5** Effect of *Njavara* rice bran on the textural properties of sweetened yoghurt: (i) firmness (g); (ii) consistency (g.sec); and (iii) cohesiveness (g). Each observation is a mean ± SD of three replicates (n=3). <sup>ab</sup> means values of treatments within a graph with different letters significantly differ ( $P \leq 0.05$ )

stiffness exhibited a significant decrease of 46.6% compared to the control group when the percentage of rice bran scaled to 3.0%. In their study, Raju and Pal (2014) observed a reduced hardness value of *misti dahi* when supplemented with dietary fibres.

The concept of consistency pertains to the firmness, thickness, or viscosity of a liquid or semi-solid substance. A significant drop in the consistency of the yoghurt was observed as the concentration of rice bran increased ( $P \leq 0.05$ ). The observed loss in consistency when larger levels of rice bran (7% and 10%) were added can be attributed to the induced separation of whey, resulting in an inconsistent firmness and consistency of the product. The decrease in hardness and consistency of yoghurt added with rice bran can be attributed to the interactions between the fibre and milk solids, leading to a compromised gel formation. In a study conducted by Wu et al. (2023), it was shown that the incorporation of rice bran led to a comparable reduction in the overall consistency of the yoghurt. A 46.67% decrease in consistency was seen when the concentration of rice bran

increased from 0% in the control group to 3%. In contrast, Fernandez-Garcia and McGregor (1997) documented that the increase in fibre quantities led to improvements in the consistency and texture of yoghurt.

The cohesiveness of food exhibits a direct correlation with its tensile and compression strength. The measure of cohesiveness indicates the extent of deformation a material undergoes before rupture and is directly correlated with the internal strength of the material's structure. Cohesion in a product is observed when it demonstrates the ability to maintain adherence to itself when subjected to compressive or tensile stress. The cohesiveness of rice bran-fortified yoghurt was significantly lower ( $P < 0.05$ ) than the control. This observation suggests a potential association with the reduced strength of protein aggregates. Similar results have been reported by Wu et al. (2023). They observed a 42.82% reduction in the cohesiveness as the level of rice bran increased from 0 to 3%.

## Conclusion

The addition of rice bran has a significant impact on the physico-chemical characteristics of sweetened yoghurt. An increase in rice bran was associated with a decrease in yoghurt's titratable acidity. Conversely, the yoghurt's syneresis, water activity, and antioxidant activity were found to increase. Furthermore, the inclusion of rice bran in the yoghurt formulation resulted in a reduction in lightness and an increase in redness values. The sensory and textural characteristics of the yoghurt were observed to be influenced when higher quantities of rice bran (7% and 10%) were added. Based on an analysis of the physico-chemical, sensory, and textural qualities, it can be inferred that the optimal level of *Njavara* rice bran integration into sweetened yoghurt is 5%.

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