



Effect of Foxtail Millet Isolates on the Quality Parameters of Reconstituted Yogurt

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ABSTRACT

Background: The aim of the present study was to formulate a reconstituted yogurt powder enriched with foxtail millet protein.

Methods: The incorporation of foxtail millet protein in the range of 0.5-1.5% in the nutrient conditions on physicochemical and reconstitution properties of high protein fresh yogurt and reconstitution yogurt product was investigated.

Result: The results obtained that various range of protein isolate of reconstitution yogurt product was significantly different ($p < 0.05$) in the physicochemical properties such as pH, titratable acidity, total solids, water holding capacity, syneresis and color. Incorporation of millet protein isolate in both fresh and reconstitution yogurt was significantly increased nutritional properties than that control products. Similarly, the physicochemical properties such as total solids, acidity, color parameters and antioxidant properties results showed that significant increase ($p < 0.05$) in the reconstitution yogurt. The results of sensory attributes evidenced that the reconstituted yogurt had greater acceptance than the control yogurt, probably due to the addition of protein isolate which positively affected sensory properties. Results suggested that the reconstitution yogurt enriched with millet protein isolate met all nutrient, sensory attributes and physicochemical and high shelf life recommendations dairy products.

Key words: Foxtail millet protein isolates, Functional yogurt, Reconstitution yogurt product, Sensory characteristics.

INTRODUCTION

Diet and lifestyle play an important role in overall health status in population. With modernization and development in technology, there is increased availability and utilization of processed, fast food and ready-to-eat food. Many researchers have shown that majority of younger generation have a tendency to order many things online to reduce the time used for going to market and buying (Maimaiti *et al.*, 2018). Dietary habit change shows devoid of natural food components in meals which impacts on nutrition level of people and maybe protein to some extent but deficit of all essential amino acids and vitamins, minerals and functional components of food. Probiotics which are live micro-organisms found in fermented foods have an impact on gastro-intestinal tract and prevents diseases such as irritable bowel disease (IBD), irritable bowel syndrome (IBS) *etc.* Specifically Lactic Acid Bacteria (LAB), protect small intestine by improving microbial diversity, up regulating protein expression involved in homeostasis and gut integrity (Judkin *et al.*, 2020).

Millet is one of the indigenous foods known to human and has been widely used in India as a staple food for thousands of years. Millets are common and readily available food sources in arid and semiarid regions, they play an important role in the food and nutritional security of the low income peoples (Amadou *et al.*, 2013). Foxtail Millet grains are usually processed in various technologies that are used in manufacturing of food products (Akinola *et al.*, 2017). Foxtail millet is a rich source of protein and moreover it contains bioactive components enriched with the health-promoting activities. However, their presence in the Indian food basket has been declining over the years (Jukanti

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et al., 2016). The lack of technologies for their effective processing and utilization is an important reason for their refuse.

Probiotics play an important role in maintaining GI tract health. These work emerged out the notion to release the antioxidative components in reconstitution yogurt utilized with foxtail millet protein investigated the nutrient, physicochemical and sensory attributes and work could be developing a functional diet/high protein based development product from the indigenous foods available from the specific geographical trait.

MATERIALS AND METHODS

Raw materials

Foxtail millet grains for this study were procured at a organic market in Bengaluru, Karnataka, India. After the procurement of raw material, it was cleaned and stored for further use. For preparation of yogurt product development

to purchase fresh- pasteurized and homogenized double toned milk, i.e., 5 per cent of fat and 8.5 S.N.F and Starter cultures for preparing yogurt, i.e., *Streptococcus thermophilus* was obtained from Nandini store, Bengaluru, Karnataka. Other chemicals and reagents used were obtained from Merck Company, Mumbai, India and of analytical grade unless otherwise stated.

Sample processing

Foxtail millet milk powder (FMMP) was prepared by according to the procedure described by Sharma *et al.* (2018) with slight modification. Preparation of FMMP, drained millets was ground to fine slurry by using wet grinding techniques. Behind grinding, the slurry was filtered using muslin cloth and the filtrate was dehydrated. The obtained millet slurry was subjected to forced convection tray drying at 60°C for 15-16 hours. FMMP was packed in aluminum foil laminated LDPE pouches and stored at refrigerator temperature (4°C) for protein isolation.

Isolation of protein from foxtail millet milk powder

The foxtail millet protein isolation (FMPI) was prepared by according to the procedure described by Rao *et al.* (2023) with slight modification. The FMMP is mixed with distilled water at a ratio of 1:20 and adjusted to the pH of the maximal protein extraction using 1.0 M NaOH. The slurry is stirred for 30 min at 25°C and then centrifuged at 4500 rpm. The pH of the supernatant is adjusted to the pH of the minimal protein extraction (isoelectric point) with 1.0 M HCl and the slurry was stirred for 20 min at 25°C. The precipitate is separated by centrifugation at 4500 rpm for 20 min at 25°C. After obtaining the protein precipitate, pellets was collected and were kept in freeze dryer for drying. Finally, the protein isolate was collected by the powder form and then stored in hermetically sealed glass bottles at 25°C for yogurt production.

Preparation of reconstitution yogurt

Reconstituted yogurt was prepared by standard method given by Seth *et al.* (2016) with slight modification. The experiment consisted of three treatments as follows: Yogurt was supplemented with different range of foxtail millet protein isolate (S1-0.5%, S2-1% and S3-1.5%) with no incorporation of foxtail millet protein isolate used as control sample. All the variation of yogurt were prepared by heating the pasteurized and homogenized double toned milk in a milk boiler at about 90°C for 10 minutes. Milk was then cooled to 37°C for inoculating with 1 ml of starter culture along with thorough mixing for one minute for uniform distribution of culture into the whole milk. Cultured milk was transferred into 120 ml sterile cups and inoculation temperature was maintained for incubation until the semi-solid mass of yogurt was formed reaching the pH 4.5±0.1. Yogurt set in cups were stored in the refrigerator. After refrigerator the both the control and foxtail millet protein incorporated yogurt samples were spread on to the clean petri plates and kept in deep freezer for complete freezing.

Followed by freezing the samples were freeze dried at -80°C for 24 hours. Following freeze dried samples were taken out and grinded to fine powder. Reconstitution was carried out according to the method described by Ismail *et al.* (2020).

Physicochemical analysis of reconstitution yogurt

Nutritional properties

Protein and ash content were estimated as described by (AOAC, 2005). Fat content was determined using the Gerber method (ISO, 2018). The total carbohydrates content was calculated by total difference of nutrition content.

pH

pH values S4 and S1, S2 and S3 reconstitution yogurt were measured using a pH meter model 34 (Backman Instruments, Inc., Fullerton, CA, USA), previously calibrated with buffers pH 4 and 7. Using a water activity meter (Aqualab Series 4TE, Decagon Devices, Inc., USA), the water activity of S4 and S1, S2 and S3 yogurt was determined at room temperature until the values were concurrent.

Total solids

Total solid content S4 and S1, S2 and S3 yogurt powder was estimated as per the procedure by (Hooi *et al.*, 2004). 1 g yogurt was weighed and placed on initially weighed aluminium dish. It was then closed with lid and kept in hot air oven at 105°C for 24 hours. After that samples were desiccated and weighed. Total solids were calculated using the formula.

Total solids =

$$\frac{\text{Dried sample with dish weight} - \text{Dish weight}}{\text{Initial curd weight}} \times 100$$

Titrateable acidity

5 g of S4 and S1, S2 and S3 yogurt sample were kept in a conical flask and it were titrated against alkali solution of 0.1 N NaOH with the addition of phenolphthalein as indicator to the sample. The end point was denoted with transformation of colourless yogurt sample to pale pink colour.

$$\text{Formula} = \text{TA (as tartaric acid)} = (\text{ml of NaOH used} \times 0.75) / \text{ml of sample}$$

0.75 is a factor that accounts for the molar mass of tartaric acid and the concentration of the NaOH solution (typically 0.1 M).

Water holding capacity

The water-holding capacity (WHC) of S4 and S1, S2 and S3 yogurt was analyzed following the procedure of Parnell *et al.* (1986). In this assay, yogurt sample incubated in the auto clamp centrifuge tubes stirred for 20 min at 30°C and centrifuged at 3000×g for 15 min. The WHC is expressed as per cent precipitate weight over initial yogurt weight.

$$\text{WHC} = \frac{\text{Wet pellet weight}}{\text{Yogurt sample weight}} \times 100$$

Colors properties

The color was expressed by CIE color scales L^* , a^* and b^* using Hunter digital colorimeter (Model D25M, Hunter Associates Laboratory, Reston, VA). L^* represents the lightness of the sample extended from 0 (black) to 100 (white). a^* and b^* represent redness (+a) to greenness (-a) and yellowness (+b) to blueness (-b) respectively.

Syneresis index

Syneresis index was determined according to the procedure described by Ismail *et al.* (2020) with slight modification. A weight of 10 g yogurt was removed and kept into a test sieve (mesh width 0.5 mm). Whey layer was calculated after 60 min at 10°C. Syneresis was expressed as mL volume of drained whey/100 g of Yogurt.

Antioxidant properties-Reducing power

Antioxidant property of yogurt was evaluated regarding reducing power (RP) through following in vitro methods. S4 and S1, S2 and S3 yogurt variations were taken in different vials and were dissolved in 1 ml of distilled water. 100 µl of sodium phosphate buffer (100 mM, pH 7.2) and 100 µl of Potassium hexacyanoferrate (III) (1%) were added to each sterile vial and incubated at shaking water bath at 50°C for 20 min. After incubation 100 µl of TCA (10%) was added to each sterile vial and centrifuged at $3000 \times g$ for 15 min. 100 µl ml of the upper layer was added with 100 µl ml of sterile distilled water and 10 µl of ferric chloride (0.1%). The color developed was read at 700 nm absorbance.

Sensory evaluation

Sensory evaluation was carried out for both control and variation (0.5%-1.5%) yogurt powder. For this the freeze-dried yogurt powder was reconstituted with distilled water in 1:3 ratio (both control and variation) and evaluated. A sensory panel of fifteen semi-trained members were involved and a nine-point hedonic scale rating from dislike extremely to like extremely be used for evaluating the overall acceptability of samples. Mean±standard deviation is out of overall acceptability scores by fifteen-panel members.

Statistical analysis

All parameters of S4 and S1, S2 and S3 yogurt powder were carried out in triplicate and analyzed using one-way analysis of variance. Post hoc analysis was performed using Duncan's multiple range test. Statistical significance was set at 95%. All analyses were conducted using SPSS, version 23.0 (IBM Corporation, Armonk, New York).

RESULTS AND DISCUSSION

Physicochemical dimensions of fresh and reconstitution yogurt

Nutritional properties

Table 1 summarized the physicochemical properties of fresh yogurt and reconstitution yogurt for Protein, CHO, fat, ash, Total solids, pH, titrable acidity. The physicochemical

properties of fresh yogurt significantly decreased than reconstitution yogurts due to affected by freeze drying. Protein content was higher in the S3 (1.5% addition with millet protein) of both fresh and reconstitution substrate followed by S2 and S1 variation. This phenomenon is due to addition of foxtail millet protein isolate and other hand implicated as the protein found in millets contains bioactive peptides with potential benefits. It was discovered that the free amino acid composition of millet proteins improved following hydrolysis. Additionally, this process resulted in an increase in the content of hydrophobic amino acids. Furthermore, the solubility of protein isolates significantly increased after hydrolysis across a wide pH range from 2 to 10 and especially above 4 (Agarwal *et al.*, 2020). Protein ranged from 4.05 ± 0.02 to 8.02 ± 1.02 g samples respectively. The control yogurt (S4) had the lowest value for both fresh and reconstitution protein content; however, the S1, S2 and S3 sample (0.5%, 1% and 1.5% supplements of millet protein isolate) recorded significantly ($P < 0.05$) higher protein content than that of control. The Carbohydrate of the fresh yogurt observed in the range of 4.12 ± 0.03 to 5.05 ± 0.02 and reconstitution yogurt was 5.75 ± 0.03 to 5.05 ± 0.02 . Reconstitution samples were slightly increased with addition millet protein supplements. Our findings are somewhat high significant value by Ismail *et al.* (2020), who observed an whey concentrate based yogurt products respectively. The maximum carbohydrate level was noted in S4 variations of both fresh (5.12 ± 0.02) and reconstitution yogurt (5.12 ± 0.02). Fat content was slightly increased in all of the reconstitution substrates compared to the fresh yogurt. Tamime and Robinson (1985) reported that sum of water used for rehydration was lower than the amount of removed water during lypolizer. These outcomes led to more stable and nutritional yogurt product. The same pattern of increased fat content on fresh yogurt and similar in reconstitution yogurt observed resulting from water rehydration by Ismail *et al.* (2020). Interestingly, no significant difference was found for ash content of the different variation (S1, S2 and S3) of fresh (0.74 ± 0.01 to 0.73 ± 0.01) and reconstitution yogurt (1.52 ± 0.03 to 1.56 ± 0.01) samples. The S3 yogurt had the highest ash content while the lowest ash content was recorded in S4 (Table 1). Our findings are similar to those by Samtiya *et al.* (2024). Reconstitution yogurts were significantly increased than in fresh yogurt in the nutritional factors such as protein, carbohydrates, fat and ash.

pH

The quality of yogurt depends on its nutritional composition and starter culture as well as acidity level. Yogurt acidity plays a significant role in yogurt flavor (Temesgen, 2015). A low pH indicates proper fermentation and prevents the major undesirable microorganisms to grow in the product. Our findings noted significant differences ($P < 0.05$) in pH values of all fresh and reconstitution yogurt varieties studied in this work. The mean pH values of the fresh yogurt

samples remained slightly high acidic than reconstitution yogurt and, on an average, ranged from 4.23 to 4.32. All reconstitution Yogurt variation had lower pH than those of fresh Yogurts due to the level of water used for rehydration and the absorption impact during lyophilization process. The fresh yogurt sample such as S2 had the highest average pH value of 4.32 ± 0.05 whereas the S4 showed the lowest pH (4.23 ± 0.01) (Table 1). Interestingly, no significant difference was observed in supplements of millet protein yogurt samples.

Titrateable acidity

As seen in Table 1, titrateable acidity of the reconstitution yogurt and control sample was obtained no significant difference between the millet proteins-based yogurt. Bulut *et al.* (2021) stated that acidity level significantly increased due to proteolytic activity of the yogurt culture due to incorporated protein which increases the production of lactic acid. Results observed that reconstitution yogurt samples of S3 (1.88%) higher acidity, while the lowest acidity was reported in S4 control yogurt (1.72%).

Syneresis

Syneresis plays a vital role of structural character of set-type yogurts (Olagunju *et al.*, 2020). The syneresis findings of the millet protein supplement yogurt samples are illustrated in Table 1. Results obtained that Syneresis content was higher in the fresh yogurt control (S4-Without millet protein isolate) sample compared to other millet protein supplement yogurt. All reconstitution yogurts noted that no syneresis up to two hours. A fresh yogurt Syneresis values was reported ranged from 31.5 ± 0.08 to 24.7 ± 0.03 per cent. According to these findings, there was no significant difference between the fresh yogurts variation.

Totals solids

The effect of incorporation of millet protein isolate on total solids of both fresh and reconstitution yogurt was illustrated in Table 1. The total solids content in reconstitution yoghurts was high and fresh yogurt content was lesser in the all products compared to fresh yogurt due to addition of water substances.

Water holding capacity

A reconstitution yogurt of WHC isolate was significantly decreased than fresh yogurt product. On other hand, Addition of millet protein during yogurt preparation significantly increased the WHC of fresh and rehydrated yogurts. The same pattern that addition of whey protein concentrates in yogurt samples the enhanced water-holding capacity (Akalin *et al.*, 2012). These findings obtained that freeze-drying and water used in rehydration of yogurt powder influenced the WHC of reconstitution yogurts. The WHC observed lesser values in all reconstitution yogurts. The decrease of WHC, upon freeze drying ranged from 58.5% in the control yogurt to 57.3% in Yogurt containing millet protein.

Table 1: Physicochemical properties fresh and reconstitution yogurts (g/100 g).

Properties	Fresh yogurt				Reconstitution yogurt			
	S1	S2	S3	S4	S1	S2	S3	S4
Protein %	5.75 ± 0.03^c	6.05 ± 0.12^b	8.02 ± 1.02^a	4.05 ± 0.02^d	9.02 ± 0.02^c	10.51 ± 0.05^b	12.05 ± 0.06^a	8.32 ± 0.05^d
CHO %	4.12 ± 0.03^d	4.21 ± 0.01^c	4.28 ± 0.05^b	5.12 ± 0.02^a	5.05 ± 0.02^d	5.10 ± 0.05^c	5.14 ± 0.03^b	5.75 ± 0.03^a
Ash %	0.73 ± 0.01^a	0.73 ± 0.05^a	0.74 ± 0.01^a	0.70 ± 0.01^b	1.52 ± 0.05^a	1.55 ± 0.02^a	1.56 ± 0.01^a	1.42 ± 0.03^b
Fat %	5.12 ± 0.05^c	5.25 ± 0.03^b	5.32 ± 0.07^a	5.05 ± 0.02^d	9.12 ± 0.12^b	9.12 ± 0.03^b	9.05 ± 0.02^c	9.63 ± 0.05^a
TS %	15.7 ± 0.05^c	16.1 ± 0.03^b	16.4 ± 0.03^a	15.7 ± 0.05^c	24.7 ± 0.02^b	26.7 ± 0.02^a	26.2 ± 0.02^a	24.3 ± 0.03^b
pH	4.28 ± 0.03^a	4.32 ± 0.05^a	4.25 ± 0.02^a	4.23 ± 0.01^a	3.37 ± 0.03^a	3.34 ± 0.03^a	3.42 ± 0.01^a	3.32 ± 0.03^a
Titrateable acidity %	0.71 ± 0.06^a	0.72 ± 0.04^a	0.74 ± 0.01^a	0.70 ± 0.10^a	1.85 ± 0.04^a	1.82 ± 0.03^a	1.88 ± 0.05^a	1.72 ± 0.01^b
Syneresis index%	24.7 ± 0.03^b	25.3 ± 0.17^b	25.2 ± 0.02^b	31.5 ± 0.08^a	NS	NS	NS	NS
WHC %	75.7 ± 0.05^b	76.2 ± 0.12^b	77.3 ± 0.02^a	70.3 ± 0.02^c	54.3 ± 0.05^c	56.2 ± 0.02^b	57.3 ± 0.02^a	58.3 ± 0.02^b

S1: 0.5% of containing of millet protein isolate; S2: 1.5% of containing of millet protein isolate; S3: 1.5% of containing of millet protein isolate; S4: Control yogurt. TS: Total solids; CHO: Carbohydrates; WHC: Water holding capacity. Different letters (a-d) in the same row indicate significant statistical differences (Duncan's test $P < 0.05$).

Color properties

Yogurt color features are important since they affect the perception and product acceptance of the customer. Color parameters of the fresh yogurt and reconstitution yogurt are illustrated in Table 2 with different concentration of millet protein isolate. Lightness or darkness (L^*), Redness ($+a^*$) or Greenness ($-a^*$) and Yellowness ($+b^*$) or Blueness ($-b^*$) explain the color parameters of yogurt. The volume of water added to reconstitution yogurts was 83 per cent of the detached water by sublimation during the lypolization. Results show that color values were significantly difference ($p>0.01$) in fresh yogurt and reconstitution yogurt samples. The control samples (S4) had a higher L^* value than S1, S2 and S3 in both fresh and reconstitution yogurt. These findings are impact to the increases the concentration of the millet protein supplement in yogurt. Addition of millet protein significantly decreased the L^* value but significantly increased a^* and b^* in both fresh isolate and reconstitution yogurt (Table 2). The a^* of fresh yogurt and reconstitution yogurt was highest in yogurt containing 1.5% (S3) of millet protein where it recorded (-1.39 ± 0.01 and -1.59 ± 0.01), followed by (-1.57 ± 0.01 and -1.79 ± 0.01) and (-2.04 ± 0.01 and -2.39 ± 0.01). For yogurts containing 1% (S2) and 0.5% (S1), respectively. The lowest a^* was -2.13 ± 0.01 for the non-supplement control yogurt. Concentration and variation of the millet protein have reported a significant difference with in the a^* range of the both fresh yogurt and reconstitution yogurt ($p<0.05$). Similar to the b^* color parameters, millet protein supplement in both fresh and reconstitution yogurt was substantially ($p<0.05$) increased. The b^* values were all reports positive, while the reconstitution yogurt, control was the only yogurt that had a lower b^* value that the variation samples. The increased in b^* of variation might be due to presence of natural pigments of the foxtail millet.

The reducing power systems were used to determine the antioxidant effectiveness. Table 2 showed the results of reducing power (ranging from 0.95 to 0.56 OD value) of the both the fresh yogurt and reconstitution yogurt addition by millet protein at different concentration. All of the fresh and reconstitution products, except that S1, had considerably ($p>0.05$) eminent reducing power compared to the control product. Several findings have confirmed the hydrolysis proteins into small peptides through fermentation to improve the effectiveness of antioxidants (Xiao *et al.*, 2015). In addition, a significant difference the activity of antioxidants has been found to be positively connected to the level of proteolysis. Gan *et al.* (2017) observed that phenolic compounds, free amino acids and lactic acid generated by the fermentation of legumes can enhance the antioxidant capacity of the products.

Sensory characteristics

Table 3 shows the sensory characteristics of yogurts. Flavor score of Yogurt containing 1% (S2) of millet protein supplement in both fresh and reconstitution types recorded the highest sensory scores, where they were 7.5 ± 0.05 and

Table 2: Color properties and reducing power of fresh and reconstitution yogurts.

Properties	Fresh yogurt				Reconstitution yogurt			
	S1	S2	S3	S4	S1	S2	S3	S4
Color properties								
L^*	75.3 ± 0.03^b	73.2 ± 0.02^c	70.2 ± 0.12^d	77.2 ± 0.05^a	70.2 ± 0.01^b	69.2 ± 0.02^c	68.2 ± 0.02^c	72.3 ± 0.03^a
a^*	-2.04 ± 0.01^c	-1.57 ± 0.01^b	-1.39 ± 0.01^a	-2.13 ± 0.01^d	-2.39 ± 0.01^c	-1.79 ± 0.01^b	-1.59 ± 0.01^a	-2.59 ± 0.01^d
b^*	8.6 ± 0.10^c	10.7 ± 0.06^b	12.6 ± 0.052^a	5.61 ± 0.10^d	8.65 ± 0.06^c	11.2 ± 0.05^b	12.03 ± 0.10^s	5.8 ± 0.12^d
Reducing power (O.D value)	0.68 ± 0.02^c	0.73 ± 0.05^b	0.90 ± 0.03^a	0.58 ± 0.02^d	0.78 ± 0.03^c	0.82 ± 0.024^b	0.92 ± 0.03^a	0.62 ± 0.01^d

S1: 0.5% of containing of millet protein isolate; S2: 1.5% of containing of millet protein isolate; S3: 1.5% of containing of millet protein isolate; S4: Control Yogurt. L^* : Lightness and Darkness; a^* : Redness and greenness; b^* : Yellowness and blueness; RP- Reducing power different letters (a-d) in the same row indicate significant statistical differences (Duncan's test $P<0.05$).

Table 3: Sensory Characteristics of fresh and reconstitution yogurts.

Sensory characteristics	Fresh yogurt				Reconstitution yogurt			
	S1	S2	S3	S4	S1	S2	S3	S4
Appearance score	7.5±0.10 ^b	7.42±0.15 ^c	6.9±0.05 ^d	7.7±0.06 ^a	7.3±0.10 ^b	7.1±0.05 ^c	6.8±0.12 ^d	7.6±0.15 ^a
Color score	7.4±0.10 ^a	7.1±0.10 ^b	7.0±0.10 ^{b c}	7.5±0.10 ^a	7.3±0.11 ^a	7.0 ±0.10 ^b	6.9±0.10 ^{bc}	7.3±0.10 ^a
Flavor score	7.3±0.10 ^b	7.5±0.05 ^a	7.4±0.10 ^b	6.9±0.10 ^d	7.2±0.10 ^b	7.3±0.10 ^a	7.2±0.05 ^b	6.8 ±0.12 ^c
Texture score	7.3±0.10 ^c	7.6±0.16 ^b	7.7±0.11 ^a	6.9±0.10 ^d	7.2±0.10 ^{bc}	7.4±0.05 ^b	7.6±0.16 ^a	6.6±0.20 ^d
Taste score	7.5±0.10 ^b	7.2±0.12 ^c	7.0±0.10 ^c	7.5±0.10 ^a	7.5±0.05 ^b	7.0± 0.15 ^c	7.0±0.15 ^c	7.6±0.10 ^a
Overall acceptability score	7.4±0.10 ^b	7.6±0.15 ^a	7.2± 0.15 ^c	7.00±0.10 ^d	7.3±0.15 ^c	7.5±0.10 ^a	7.3±0.12 ^b	7.0±0.10 ^d

S1: 0.5% of containing of millet protein isolate; S2: 1.5% of containing of millet protein isolate; S3: 1.5% of containing of millet protein isolate; S4: Control Yogurt. Different letters (a-d) in the same row indicate significant statistical differences (Duncan's test P<0.05).

7.3±0.10, respectively. Yogurt, reconstitution with water from 30 days stored lyophilized powder kept at ambient temperature, had fine properties (Chutrtong, 2015). The highest overall acceptability scores were reported for Yogurt containing S2, followed by the S1(0.5%) then yogurt containing S3 (1.5%) and finally, yogurt containing without millet protein supplements (Control S4). Sensory characteristics results confirmed that the reconstitution yogurt had additional acceptance than the fresh yogurt, perhaps effects to the concentration of positively influence color, texture and flavor components. The rheological manners of a reconstituted Yogurt sample were equivalent with the fresh Yogurt because the rheological properties and Yogurt structural and are directly connected to the criteria of Yogurt sensory characteristics (consistency and softness) which are closely linked to consumer recognition. Similarly, flavor and texture Sakin-yilmazer *et al.* (2014) and overall acceptance Santos *et al.* (2018) of reconstitution yogurt obtained results associated with the currents research.

CONCLUSION

The present study was conducted to prepared the lyophilized yogurt powder fortified with different concentration of millet protein (0.5%, 1% and 1.5%) could achieve yogurt with considerable enhance the physicochemical, nutritional, color parameters, antioxidant and sensory characteristics and can conquer the less shelf life of fresh yogurt and ambient temperature storage. The findings helped that effectiveness of millet protein to enhance the antioxidant in both the products. On other hand fermentation and reconstitution is an outstanding method to construct millet-based yogurt product as result of the improved in the nutritional and sensory attributes. The findings concluded that lyophilized yogurt can be promising for customers to keep ambient storage temperature and whenever to reconstitute the products as ready to health drink.

Credit authorship contribution statement

P. Vasantha Kumari: Conceptualization, Project administration, Supervision, Resources, Writing-Review and Editing. V. Padma: Project administration, Methodology, Data curation, Resources, Formal analysis. Ritika Biswas: Conceptualization, Investigation, Methodology, Data curation, Writing-original draft.

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Data availability

The data presented in this study are available on request from the corresponding authors.

Disclaimers

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Conflict of interest

The authors declare that there is no conflict of interest associated with this article.

REFERENCES

- Agarwal, C., Sajji, G.S. and Rathore, A.S. (2020) Influence of ultrasound, microwave and high pressure homogenization on the structural and functional properties of *Vigna radiata* L. proteins. *Journal of Chemical Technology and Biotechnology*. **100(11)**: 2259-2270.
- Akalın, A.S., Unal, G., Dinkci, N.A.Y.I.L. and Hayaloglu, A.A. (2012). Microstructural, textural and sensory characteristics of probiotic yogurts fortified with sodium calcium caseinate or whey protein concentrate. *Journal of Dairy Science*. **95(7)**: 3617-3628.
- Akinola, S.A., Badejo, A.A., Osundahunsi, O.F. and Edema, M.O. (2017). Effect of preprocessing techniques on pearl millet flour and changes in technological properties. *International Journal of Food Science and Technology*. **52(4)**: 992-999.
- Amadou, I., Gounga, M.E. and Le, G.W. (2013). Millets, nutritional composition, some health benefits and processing. *Emir J. Food Agric*. **25(7)**: 501-508.
- AOAC (2005). Official Methods of Analyses of the Association of Analytical Chemists. (18th ed).
- Bulut, M., Tunçtürk, Y. and Alwazeer, D. (2021). Effect of fortification of set type Yogurt with different plant extracts on its physicochemical, rheological, textural and sensory properties during storage. *International Journal of Dairy Technology*. **74(4)**: 723-736.
- Chutrtong, J. (2015). Survival of probiotic bacteria in freeze-dry yogurt starter cultures storage at 4 and 30 degree celsius. *Procedia-Social and Behavioral Sciences*. **191**: 2219-2225.
- Gan, R.Y., Shah, N.P., Wang, M.F., Lui, W.Y. and Corke, H. (2017). Lactobacillus plantarum WCFS1 fermentation differentially affects antioxidant capacity and polyphenol content in mung bean (*Vigna radiata*) and soya bean (*Glycine max*) milks. *Journal of Food processing and Preservation*. **41(1)**: e12944.
- Hooi, R., Barbano, D.M., Bradley, R.L., Budde, D., Bulthaus, M., Chettiar, M. and Reddy, R. (2004). Chapter 15 chemical and physical methods. *Standard Methods for the Examination of Dairy Products*. pp 417-431.
- Ismail, E.A., Aly, A.A. and Atallah, A.A. (2020). Quality and microstructure of freeze-dried Yogurt fortified with additives as protective agents. *Heliyon*. 6(10). doi: 10.1016/j.heliyon.2020.e05196.
- ISO 19662:2018 | IDF 238:2018. Milk-determination of Fat Content-Acido-butyrometric (Gerber method).
- Jukanti, A.K., Gowda, C.L., Rai, K.N., Manga, V.K. and Bhatt, R.K. (2016). Crops that feed the world 11. Pearl Millet (*Pennisetum glaucum* L.): An important source of food security, nutrition and health in the arid and semi-arid tropics. *Food Security*. **8**: 307-329.
- Judkins, T.C., Archer, D.L., Kramer, D.C. et al. (2020). Probiotics, Nutrition and the Small Intestine. *Curr Gastroenterol Rep*. **22(2)**. <https://doi.org/10.1007/s11894-019-0740-3>.
- Maimaiti, M., Zhao, X., Jia, M., Ru, Y. and Zhu, S. (2018). How we eat determines what we become: Opportunities and challenges brought by food delivery industry in a changing world in China. *European Journal of Clinical Nutrition*. **72(9)**: 1282-1286.
- Olagunju, A., Omoba, O., Enujiugha, V., Alashi, A. and Aluko, R. (2020). Technological properties of acetylated pigeon pea starch and its stabilized set-type Yogurt. *Foods*. **9(7)**: 957. <https://doi.org/10.3390/foods9070957>.
- Parnell-Clunies, E.M., Kakuda, Y., Mullen, K., Arnott, D.R. and deMan, J.M. (1986). Physical properties of yogurt: A comparison of vat versus continuous heating systems of milk. *J. Dairy Sci*. **69**: 2593-2603.
- Rao, M.V., Sunil, C.K. and Venkatachalapathy, N. (2023). Effect of microwave and hot air radiofrequency treatments on physicochemical and functional properties of foxtail millet flour and its protein isolate. *Journal of Cereal Science*. **114**: 103774. doi: 10.1016/j.jcs.2023.103774.
- Sakin-Yilmazer, M., Koç, B., Balkir, P. and Kaymak-Ertekin, F. (2014). Rheological behavior of reconstituted yogurt powder-An optimization study. *Powder Technology*. **266**: 433-439.
- Samtiya, M., Badgujar, P.C., Chandratre, G.A., Aluko, R.E., Kumar, A., Bhushan, B. and Dhewa, T. (2024). Effect of selective fermentation on nutritional parameters and techno-functional characteristics of fermented millet-based probiotic dairy product. *Food Chemistry*. **17(22)**: 101483. doi: 10.1016/j.fochx.2024.101483.
- Santos, G.D., Nogueira, R.I. and Rosenthal, A. (2018). Powdered Yogurt produced by spray drying and freeze drying: A review. *Brazilian Journal of Food Technology*. **21**: e2016127. doi: 10.1590/1981-6723.12716.
- Seth, D., Mishra, H.N. and Deka, S.C. (2016). Functional and reconstitution properties of spray-dried sweetened yogurt powder as influenced by processing conditions. *International Journal of Food Properties*. **20(7)**: 1603-1611. <https://doi.org/10.1080/10942912.2016.1214965>.
- Sharma, N. and Niranjana, K. (2018). Foxtail millet: Properties, processing, health benefits and uses. *Food Reviews international*. **34(4)**: 329-363.
- Tamime, A.Y. and Robinson, R.K. (1985). Yogurt: Science and Technology (pp. xiii+431pp).
- Temesgen, M. and Yetneberk, S. (2015). Effect of application of stabilizers on gelation and syneresis in Yogurt. *Food Sci Qual Manag*. **37(2005)**: 90-103.
- Xiao, Y., Wang, L., Rui, X., Li, W., Chen, X., Jiang, M. and Dong, M. (2015). Enhancement of the antioxidant capacity of soy whey by fermentation with *Lactobacillus plantarum* B1-6. *Journal of Functional Foods*. **12**: 33-44.