

Full Length Research Paper

Successful value-chain approach for oat industry; development and quality evaluation of oat (*Avena sativa*) incorporated yogurt

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Oat (*Avena sativa*) is a cereal rich in fiber and nutrients necessary for good health. This study was conducted to develop oat flakes incorporated yogurt. Oat flake concentrations were used at 2.5, 3.75, and 5 g of oats per 100 ml of milk. The selected oat concentration from a sensory evaluation was compared with a commercial yogurt for consumer preference and proximate analysis. The shelf life of the selected yogurt sample was determined by measuring total soluble solids, pH, titratable acidity, and the rate of syneresis. The microbiological assessment was carried out by the total plate count method and yeast and mold count for 21 days. Statistical analysis of data was done using SSPS and SAS at $p < 0.05$ significance level. Most consumer preferable oat concentration was 3.75 g oats per 100 ml of milk, and its sensory parameters were similar to the commercial yogurt. The selected oat concentration showed significantly higher values for fat, protein, solids non-fat, and fiber contents than the commercial yogurt. The shelf life of oat yogurt was 14 days from the production according to the yeast and mould count. In summary, oat flakes incorporated set yogurt can be developed with a reasonable shelf life, better sensory attributes, and higher nutrient content than the commercial yogurt.

Key words: Oat, physico-chemical properties, proximate analysis, yogurt, shelf life.

INTRODUCTION

Chronic diseases like cancers, diabetes, and heart-related diseases are widely spreading throughout the world causing a significant number of deaths (Wang et al., 2016). Unfortunately, these diseases sometimes appear in the early stages of life. This prevalence of non-

communicable diseases has become a global crisis due to unhealthy diet plans among humans (Varma et al., 2016). As an attempt to overcome this issue, people around the world give considerable attention to healthy foods and beverages. Healthy foods command increasing

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demand worldwide. Interestingly, cereals are incorporated in developing functional foods as a new trend in food technology to increase the nutritional profile of foods and beverages (Gasmalla et al., 2017).

Oat (*Avena sativa*), a cereal considered as a functional food, belongs to the family *Poacea*. Oat is important in promoting good health among people in numerous ways (Sterna et al., 2016). It is rich in antioxidants like avenanthamides and water-soluble fiber β – glucan (Henrion et al., 2019; Varma et al., 2016). β – glucan shows hypoglycemic properties that stimulate insulin secretion to control the blood sugar level. This soluble fiber, also, contributes to preventing cardiovascular diseases and other obesity-related diseases (Wu et al., 2019). Oat incorporated foods have shown a positive impact on human health such as lowering blood cholesterol, reducing blood sugar level, reducing hypertension or high blood pressure, improving bowel function, and controlling obesity (Tiwari et al., 2017). Yogurt, as a food frequently consumed by people of all age groups, is undoubtedly a promising food item for the incorporation of oats in the formulation of functional food.

According to the Food and Drug Administration (FDA, 2019), yogurt is a fermented dairy product which is produced by culturing one or more basic ingredients (cream, milk, partially skimmed milk, skimmed milk, or other reconstituted versions of these ingredients may be used alone or in combination) and any of the optional dairy ingredient with a characterizing bacteria culture which contains *Streptococcus salvarius* sub sp *thermophilus* and *Lactobacillus delbrueckii bulgaricus*. Yogurt is one of the most easily digestible dairy products (Tamime and Robinson, 2007). Yogurt has a high nutritional profile with protein, milk carbohydrates, vitamins, and minerals. It is an important food as a probiotic carrier to humans to improve human gut health (Pei et al., 2017). Although yogurt itself shows a high nutritional profile and health effects, value addition for yogurt has been researched to further improve its nutrition value. A study has proved that yogurt enriched with β - glucan can be used as an effective dietary therapy for hypercholesterolemia (Ahmed et al., 2017). Incorporation of fibers in yogurt has become a novel technique to enhance the fiber consumption among people (Dabija et al., 2018). However, reports on the incorporation of oat flakes that most probably may give a high nutritional, functional, and sensorial effect to yogurt are lacking in the literature. This study was conducted to develop an oat incorporated yogurt with favorable nutritional and sensory properties with a reasonable shelf life as a functional food.

MATERIALS AND METHODS

Oat flakes (Stassen group, Colombo, Sri Lanka), full cream fresh milk with acceptable organoleptic and microbial quality, sucrose, non-fat milk powder (Fonterra Brands, Sri Lanka), and potassium sorbate (INS No. 202) were purchased from a local retail shop. The

starter culture with *Streptococcus thermophilus* and *Lactobacillus bulgaricus* was purchased from the Veterinary Research Institute, Gannoruwa, Sri Lanka.

Preparation of oat incorporated yogurt

Preparation of oat yogurt was done according to the following procedure (Figure 1). Gelatin (7.5 g) was dissolved in slightly warm water (20 ml) at 60- 65°C before mixing up with the mixture. Three different oat concentrations were used to prepare oat yogurts according to Table 1.

Sensory evaluation

A non-trained panel of 50 members was selected from the university premises for the sensory evaluation. The panel was with 25 men and 25 women. A five-point hedonic scale (1 – Not acceptable, 2 – Poor, 3 – Fair, 4 – Good, 5 - Excellent) was used to evaluate color, appearance, odor, sweetness, sourness, taste, overall quality, and purchasing intension as sensory parameters. The selected oat concentration (T2) from the first sensory evaluation was then evaluated against a commercial yogurt sample using a non-trained panel of 30 members. The panel was with 15 men and 15 women. Age of the both panel members were varied from 24 to 40.

Proximate analysis of oat yogurt and commercial yogurt

Moisture content (MC %), ash content, and total solid content (TS %) were determined using the methods recommended by the Association of Official Analytical Chemists (2005). Crude protein content was determined using the Kjeldahl distillation method and crude fat content was determined using the Soxhlet extraction method (AOAC, 2005). Solid non-fat content (SNF %) was determined using Sri Lanka standard 824 (1989) and crude fiber content was determined using crude fiber analyzer. A calculation method (Energy (kcal) = weight of carbohydrate \times 4 kcal/g + weight of protein \times 4 kcal/g + weight of fat \times 9 kcal/g) was used to determine the energy content (James, 1995).

Shelf-life evaluation of oat yogurt

Physicochemical parameters of oat yogurt

Refrigerated (4°C) yogurt samples were used. A digital pH meter (Model: pp – 206, EZODO) was used to measure the pH of the yogurt samples. Total soluble solids (TSS) content was determined by a handheld refractometer (Model: ATAGO N – 46, Japan) as a percent value in Brix%. Titratable acidity (TA %) was determined by titration of yogurt samples against 0.1 N NaOH using phenolphthalein as the indicator according to the AOAC 947.05 method (AOAC, 1990). The previously mentioned tests were conducted at 3-day intervals for 21 days. The rate of syneresis was determined for 21 days with 7-day intervals. Yogurt sample was well stirred and 10 g was weighed. The weighed sample was placed on a whatman filter paper (110 mm) and allowed to drain off for 10 min. Weight loss was measured (Wijesinghe, 2015).

Microbiological assessment

The microbiological assessment was carried out for 21 days with 7-day intervals. Yogurts were stored at 4°C and 1 g of a yogurt sample was mixed with 9 ml of 0.1% peptone. A dilution series was

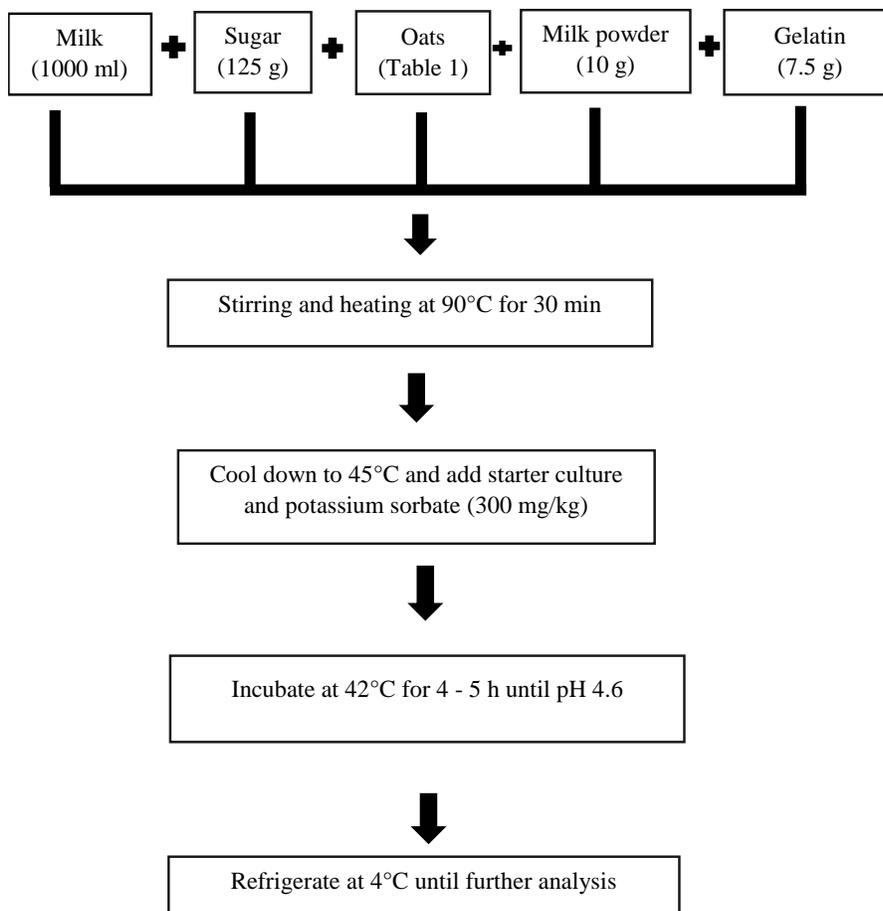


Figure 1. Flow diagram for preparation of oat yogurt.

Table 1. Three different oat concentrations were used to prepare yogurts.

Concentration	Oat concentration (g per 100 ml of milk)
T ₁	2.5
T ₂	3.75
T ₃	5

T₁ – Oat concentration 1, T₂ – Oat concentration 2, T₃ – Oat concentration 3.

prepared up to 10^{-5} . The dilution 10^{-5} was selected for the bacterial colony count while the dilution 10^{-1} was selected for the yeast and mould count. Nutrient agar was used for the bacterial colony count while potato dextrose agar was used for yeast and mould count as growth media, and 0.1 ml of the dilute was spread on the agar which was then incubated at 37°C (SLS 824, 1989).

Statistical analysis

Sensory evaluation data were analyzed by the non-parametric analysis method (Kruskal Wallis test) by SSPS statistical software and parametric data analysis was conducted by Analysis of Variance (ANOVA) using SAS statistical software at $p < 0.05$ significance level.

RESULTS AND DISCUSSION

Sensory evaluation

There was a significant difference ($p < 0.05$) in color, appearance, odor, sweetness, taste, texture, overall quality, and purchasing intension except sourness among the three different oat concentrations (Figure 2). T₃ which contained the highest amount of oats showed the lowest mean ranks for all sensory attributes. There was no significant difference in color, appearance, odor, sweetness, sourness, and overall quality except in texture and purchasing intension between T₁ (2.5 g of

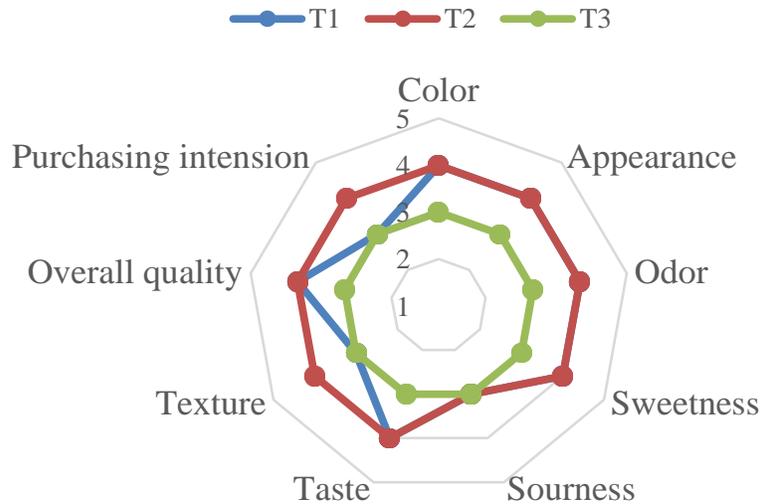


Figure 2. Median ranks obtained for sensory attributes of oat incorporated yogurt (T1 – Oat 2.5 g per 100 ml of milk, T2 - Oat 3.75 g per 100 ml of milk, and T3- Oat 5 g per 100 ml of milk).

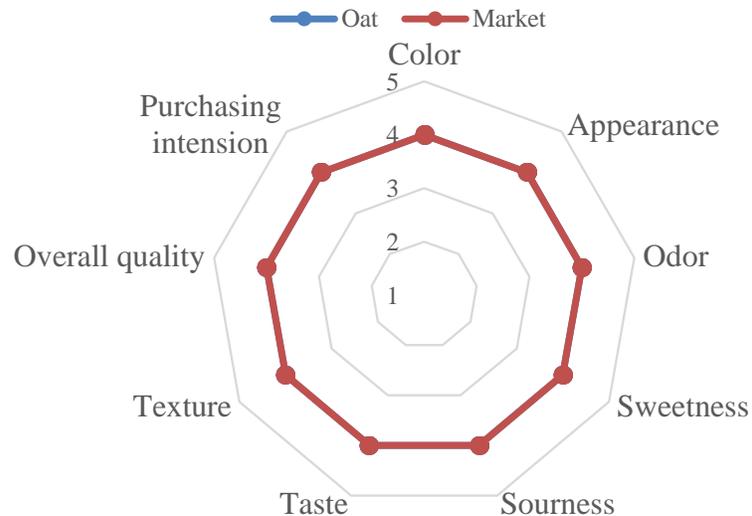


Figure 3. Median ranks obtained for sensory attributes of oat yogurt T₂ (selected through T₁, T₂, T₃) and commercial yogurt.

oats per 100 ml of milk) and T₂ (3.75 g of oats per 100 ml of milk). Finally, T₂ was selected as the best oat concentration as the intended objective of this study was in line with incorporating the highest quantity of oats possible in yogurt.

The second sensory evaluation was conducted to compare the selected oat concentration from the first sensory evaluation and commercial yogurt. There was no significant difference in color, appearance, taste, texture, overall quality, purchasing intension, odor, sweetness, and sourness between oat yogurt and commercial yogurt (Figure 3).

Proximate analysis of oat yogurt

Results of proximate analysis of oat yogurt and commercial yogurt are given in Table 2. There was a significant difference ($p < 0.05$) in moisture content between the two yogurt samples. Commercial yogurt had a higher moisture content (70.23%) than oat yogurt (65.77%). This decrease in moisture content was due to the incorporation of oat flakes into the yogurt. Also, the total solid contents of the two yogurt samples were significantly different. Oat yogurt had a higher mean value for total solid (TS %) content ($36.38 \pm 0.3\%$) than

Table 2. Variation of proximate parameters between oat yogurt and commercial yogurt.

Proximate component	Commercial yogurt	Oat yogurt
MC%	70.23 ± 1.1 ^a	65.79 ± 1.0 ^b
TS%	30.23 ± 0.7 ^b	36.38 ± 0.3 ^a
Ash%	0.28 ± 0.2 ^a	0.37 ± 0.3 ^a
Protein%	3.00 ± 0.05 ^b	6.20 ± 0.05 ^a
Fat%	3.00 ± 0.0 ^b	6.10 ± 0.8 ^a
SNF%	32.50 ± 0.3 ^b	41.76 ± 0.6 ^a
Fiber%	0.00 ± 0.0 ^b	0.36 ± 0.5 ^a
Carbohydrate%	23.49 ^a	21.18 ^b
Energy(kcal/100 g)	140.33 ^a	164.56 ^b

The same letter in each row represents values not significantly different from each other ($p < 0.05$)
 MC – Moisture content, TS – Total solid content, SNF – Solid Non-Fat content

commercial yogurt which had a TS% of 30.23±0.7%. Increment of TS% in oat yogurt is due to the addition of oat flakes that increase the solid content per a given mass. There was no significant difference ($p > 0.05$) in ash content between the two yogurt samples.

The protein content of commercial yogurt showed a mean value of 3.0±0.0% while the protein content of oat yogurt was 6.2±0.0%. Yogurt should contain a minimum of 2.7% of protein content according to the CODEX standard (Codex Stan 243, 2003) and thus oat yogurt has acceptable protein content. Interestingly, oat yogurt had a considerably higher percentage of protein content due to the incorporation of oats as oat is a protein-rich cereal (Varma et al., 2016). The fat contents of the two yogurt samples exhibited a significant difference ($p < 0.05$). Commercial yogurt had a mean value of 3.0±0.0% while oat yogurt had a fat content of 6.1±0.8%. The high-fat content of the oat yogurt was due to the high-fat content of oat grains (Varma et al., 2016). According to CODEX, the maximum fat content of yogurt should be 15%. According to the SLS standard, the minimum fat content of yogurt should be 3%. Oat yogurt is in an acceptable stage concerning fat content and the high-fat content may have contributed to the consistency of the oat yogurt.

The solid-non-fat (SNF) content of the two yogurt samples showed a significant difference. Commercial yogurt had an SNF of 32.5±0.3% while oat yogurt had a SNF of 41.76±0.6%. These results indicate that the SNF content was higher due to the incorporation of oats. SNF mainly contains lactose, protein, and mineral matter (Tamime and Robinson, 2007). Yogurt should contain a minimum of 8.0% of SNF content (SLS standard., 1989). Therefore, oat yogurt consists of an acceptable level of SNF. The high protein content of oats can directly affect the SNF value of the treated yogurt. The fiber content of the two yogurt samples was, also, significantly different ($p < 0.05$) due to the absence of fiber in commercial yogurt. Oat is a fiber-rich cereal (Varma et al., 2016). The fiber content of oat yogurt was 0.36±0.1%. This is the most beneficial point of this product because fiber is one of the

most essential dietary components for human health. The carbohydrate content of oat yogurt was 21.18% while that of commercial yogurt was 23.49%. The 2% decrease in the carbohydrate content of the oat yogurt may be due to the higher quantities of proteins and lipids of this product. Lactose is the major sugar in yogurt (Tamime and Robinson, 2007) contributing much to the carbohydrate content of yogurts. Nevertheless, all carbohydrates, fat, and protein act as the main sources of energy. The energy value of commercial yogurt was 140.33 kcal/100 while that of oat yogurt was 164.56 kcal/100 g. The higher energy value of oat yogurt is due to higher protein and fat content. This proves that consumption of oat yogurt gives a higher energy value. Therefore, this is more suitable as a perfect breakfast meal for people of all age groups (Varma et al., 2016).

Shelf life evaluation of oat yogurt

Physicochemical parameters

The variation of physicochemical parameters with time is given in Table 3. There is a significant difference in variation of pH, TA, and TSS with time. The reduction of pH value and increment of TA is due to the increment of lactic acid production by lactic acid bacteria (Ibrahim et al., 2019). Titratable acidity (TA) and pH values are in the acceptable range for 21 days (SLS 824, 1989). TSS of oat yogurt, expressed in Brix% values, increased with time. This variation may be due to the removal of water during the fermentation process by lactic acid bacteria.

Variation of syneresis with time indicates the variation of whey separation with time. Syneresis has a significant increment with storage time for this treated yogurt (1.96-3.93) (Table 4).

Microbiological assessment for oat yogurt

Bacterial colony count and yeast and mold count showed

Table 3. Variation of physicochemical parameters of oat yogurt stored under refrigerated temperature (4°C).

Days	pH	TSS (%)	TA (%)
1	4.62 ± 0.0 ^a	31.50 ± 0.5 ^f	0.72 ± 0.0 ^d
3	4.55 ± 0.0 ^b	33.83 ± 0.2 ^e	0.78 ± 0.0 ^{cd}
6	4.50 ± 0.0 ^c	34.40 ± 0.1 ^{de}	0.85 ± 0.0 ^{bc}
9	4.45 ± 0.0 ^d	34.80 ± 0.2 ^d	0.90 ± 0.0 ^b
12	4.41 ± 0.0 ^e	34.83 ± 0.2 ^d	1.04 ± 0.0 ^a
15	4.38 ± 0.1 ^f	36.50 ± 0.5 ^c	1.05 ± 0.0 ^a
18	4.29 ± 0.1 ^g	38.16 ± 0.7 ^b	1.08 ± 0.0 ^a
21	4.18 ± 0.0 ^h	39.16 ± 0.7 ^a	1.08 ± 0.0 ^a

The same letter in each column represents values not significantly different from each other ($p < 0.05$).

Table 4. Variation of syneresis with time.

Days	Syneresis (%)
1	1.96 ± 0.01 ^d
7	2.22 ± 0.37 ^c
14	3.23 ± 0.05 ^b
21	3.93 ± 0.02 ^a

The same letter in each column represents values not significantly different from each other ($p < 0.05$).

Table 5. Variation of bacterial colony count and yeast and mould count with time.

Days	Bacterial count(log cfu/g)	Yeast and Mould count(log cfu/g)
1	7.91 ^d	—
7	8.55 ^c	2.16 ^c
14	8.85 ^b	2.95 ^b
21	9.26 ^a	3.44 ^a

The same letter in each column represents values not significantly different from each other ($p < 0.05$).

a significantly different increment with time (Table 5). According to SLS 824 (1989), bacterial colony count was at an acceptable level up to 21 days. Yeast count has exceeded the maximum colony count in the third week as per the SLS 824(1989). This indicates that oat yogurt is more suitable to consume until 14 days from the day of production at this preservative level (300 ppm). However, it can be increased by adding potassium sorbate up to 1000 ppm according to Laws and Regulations (Country report) applicable to food and food additives in Sri Lanka.

Conclusion

A consumer preferable oat incorporated yogurt production is possible with oat flakes up to 3.75 g per 100 ml of milk. This product is similar to the commercial yogurt according to the sensory attributes considered in this study. Strikingly, this product has a considerably high nutrient

profile with high protein, fat, and energy values. The pH, TSS, and TA variation of the developed oat yogurt was in an acceptable range during 21 days. This product stored at 4°C is microbial safe to consume for up to 14 days. The findings can be used to conduct further developments of oat yogurt and to introduce this product to the Sri Lankan dairy industry to fulfill the daily nutrient requirements of people of all age and to use as an effective functional food.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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