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Development and Analysis of Physico-Chemical Properties of Set Yogurt Dual Fortified with Oat Powder and Ripe Jackfruit Flesh Pulp

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Abstract

Background: Functional foods fortified with cereals and fruit pulp have shown high consumer demand mainly due to their health benefits. This study aimed at developing a dual fortified set yogurt incorporating oat (*Avena sativa*) powder, which is a rich source of nutrients and fibre, and ripe jackfruit (*Artocarpus heterophyllus*) flesh pulp, which is a rich source of nutrients and bioactive agents, as a functional food.

Methods: Oat (3.75% w/v) fortified set yogurt was prepared by incorporating ripe jackfruit pulp at 10%, 20%, 30% w/v quantities. The shelf life study of the developed yogurt was evaluated by measuring physicochemical properties such as pH, titratable acidity (TA), total soluble solids (TSS), syneresis and firmness, and by investigating the total plate count, and yeast and mould count for 21 days.

Results: Sensory analysis revealed that the 10% fruit pulp added yogurt was most accepted, which was hence chosen for further analysis. According to proximate analysis, the developed yogurt was higher in many nutrients, including protein, fat and fibre, than a market yogurt. Further, the developed yogurt can be used as a high-energy low-carbohydrate yogurt.

Conclusions: All the physicochemical parameters were within the acceptable levels up to 12-15 days and microbial safety was adequate up to 14 days. Thus, this product has potential to become a fermented milk based product with favourable sensory properties, which can be promoted as a healthy food product.

Keywords: Jackfruit, Oat, Physicochemical Properties, Proximate Analysis, Set Yogurt

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INTRODUCTION

Formulation of functional foods fortified or enriched with numerous nutrients, is given much emphasis at present. Such approaches often enhance the ability of the consumers to prevent or combat numerous non-communicable diseases such as diabetes, high blood pressure, hypercholesterolemia and cancer [1–4]. Active ingredients used in the formulation of functional foods giving such health benefits are of various types and include vitamins such as vitamin B and D [5–6], minerals such as calcium and iron [7–8], plant derived ingredients such as phenolic compounds or extracts, essential oils and dietary fibre [9], and animal derived ingredients such as omega-3 fatty acids [10]. Interestingly, formulation of fruit pulp incorporated functional foods is extensively studied, due to the high demand and health benefits associated with the fruit pulps [11].

Jackfruit (*Artocarpus heterophyllus Lam*.) is a major fruit native to India and found commonly in the tropics. Jackfruit flesh pulp is highly nutritious and possesses active ingredients that provide numerous health benefits. In addition to the starch content, which varies with the degree of maturity of the fruit and moderate fibre content, jackfruit flesh consists of a protein content of 0.57 – 0.97%. The vitamins rich in jackfruit include Vitamin C, and vitamins such as riboflavin, niacin, pyridoxine, and folic acid of the B-complex group. Minerals that improve the nutritive value of jackfruit flesh include macro elements such as calcium and magnesium and micro elements such as iron and manganese. Jackfruit is also a good source of phytochemicals that contribute much towards human health. For instance, carotenoids, a major phytochemical of jackfruit flesh, exhibits anticancer, antioxidant and anti-inflammatory properties, in addition to many other properties beneficial for health [12]. Thus, numerous functional foods, such as jam, cake, ice-cream, ready-to-serve beverages and low-fat yogurt, have been formulated incorporating ripe jackfruit flesh pulp [12–15].

Among the plentiful functional foods developed so far, functional yogurt products have secured a prominent place. It is mainly due to the high demand around the world for the fermented milk products. Yogurt fortified with minerals such as iron, calcium and zinc [16], and vitamins such as Vitamin B12 and D [17–18] have been successfully formulated and many such products have shown health benefits [17-18]. In addition, yogurts incorporated with many types of fibre or fibre sources such as psyllium husk, extruded flaxseed powder, persimmon powder and apple powder [19–21] have been successfully formulated improving the lipid profiles of the consumers [20].

Oats is a promising functional ingredient to be incorporated in yogurt as it is rich in fibre [22], nutrients such as vitamins, minerals, fat and protein [23], and bioactive agents such as antioxidants [24]. The health benefits of oats include improving of the lipid profile of hypercholesterolemic subjects, mainly due to β-glucan, and assisting in the treatment of hyperglycemia, mainly due to its low glycemic index [23]. In an attempt to transfer the health benefits of oats to the consumers via yogurt, which is a much consumer preferred food product, Malki *et al.* developed oat-flakes incorporated set-yogurt successfully [25].

Although fruits such as strawberry, blueberry, sour cherry and jackfruit have been used to make naturally flavoured yogurt [15, 26], jackfruit has not been used to flavour oat incorporated yogurt. Thus, this study aimed to develop jackfruit pulp fortified oat incorporated set yogurt as a dual fortified yogurt product, as an extension to our previous study. In addition to combining the health benefits of both jackfruit flesh and oats, incorporating the jackfruit flavour, which may enhance consumer acceptance in the yogurt product, was also targeted.

METHODOLOGY

Materials

The starter culture with *Streptococcus*

thermophillus and *Lactobacillus bulgaricus* was purchased from the Veterinary Research Institute (VRI), Gannoruwa, Sri Lanka. Oat flakes (Stassen Exports Pvt. Ltd, Colombo, Sri Lanka), full cream fresh milk with acceptable organoleptic and microbial quality (Kothmale Holdings PLC, Sri Lanka), sucrose, non-fat milk powder (Fontera Brands, Sri Lanka) and potassium sorbate (INS No.202) were purchased from a local retail shop. Also, a yogurt product with a reputed brand name was purchased from a retail shop.

Preparation of Jackfruit Flavoured Oat Incorporated (Dual Fortified) Set Yogurt

Preparation of yogurt was carried out using the procedure reported by Malki *et al.* [25] with slight modifications. Briefly, sucrose (100 g), non-fat milk powder (10 g), and oat powder sieved through a 0.18 mm sieve (3.75% w/v) were mixed with 1000 ml of full cream fresh milk. Gelatin (10 g) was dissolved in slightly warm water (60 - 65 °C) and mixed up with the other ingredients. When the mixture was heated to 80 °C, ripe jackfruit flesh pulp (10%, 20% and 30%) was mixed well according to the treatments indicated in Table 1.

Table 1: Different Jackfruit Pulp Levels used in the Study

Treatment	Jackfruit Pulp Level (w/v %)
C (Control)	-
T_1	10
T_2	20
T_3	30

The mixture was stirred well for homogenization. The yogurt mixture was pasteurized at 90 °C for 15 minutes with continuous stirring. The pasteurized yogurt mixture was cooled down to 45 °C and the yogurt starter culture was added, according to the recommendations of Veterinary Research Institute, Gannoruwa. Also, potassium sorbate (300 mg/kg) was added as the preservative. The yogurt mixture was incubated at 42 °C for 4-5 h until the pH reached 4.6. Finally, the mixture was refrigerated at 4 - 8 °C. Preliminary trials were conducted to select three different levels of jackfruit flesh pulp that can be used to incorporate in yogurt (Table 1).

Sensory Evaluation

An untrained panel of 30 members, who were selected among the university students and lecturers, carried out a sensory evaluation to select the best yogurt formulation with the highest consumer acceptance out of the four different treatments (Table 1). A 5-point hedonic scale was used to evaluate the attributes of colour, appearance, odour, sweetness, sourness, taste, overall quality and purchasing intension [25].

Physicochemical Parameters of Jackfruit Pulp and Oat Incorporated Yogurt

Yogurt was stored at refrigerated condition (4 - 8 °C). The following tests were conducted for a period of 21 days at 3-day intervals. Determination of pH was carried out by using a digital pH meter (Model: pp-206, EZODO). Total soluble solids (TSS; Brix%) was measured using a handheld refractometer (Model: ATAGO N-46, Japan). Titratable acidity was measured by titrating the yogurt samples against 0.1 N NaOH by using phenolphthalein as the indicator. Syneresis was measured for a time period of 21 days at 7-day intervals [25]. The firmness (texture) was measured using a texture analyser (ATAGO N-46, Japan).

Proximate Analysis of Jackfruit Pulp and Oat Incorporated Set Yogurt and Market Yogurt

The moisture content (MC), ash content and total solid content (TS) were determined according to the methods given by the Association of Official Analytical Chemists [27]. The crude fat content was determined by Soxhlet extraction method [27] and crude protein content was determined by Kjeldhal method [27]. The solid non-fat content (SNF) was determined according to SLS standard 824: Part 2 [28], along with the crude fibre content. The percent carbohydrate content and energy level were calculated according to

a standard formula [25]. Proximate analysis of both the developed yogurt and market yogurt was carried out.

Shelf Life Evaluation of Jackfruit Pulp and Oat Incorporated Yogurt

Shelf life evaluation of yogurt, stored at 4 – 8 °C, was carried out according to SLS 824 [28] for a time period of 21 days at 7-day intervals. Plate count agar was used for the bacterial colony count and potato dextrose agar was used for the yeast and mould count. Bacterial colony counts were taken in 24 h. The entire experiment was triplicated.

Statistical Analysis

Data of sensory evaluation was analysed by a non-parametric method (Friedman Test) while quantitative data were analysed with Analysis of Variance (ANOVA) using MINITAB (version 15) statistical software.

RESULTS AND DISCUSSION

Sensory Evaluation

The acceptance test carried out for nine attributes of yogurt samples revealed that colour, sweetness, sourness, taste, and overall quality were similar among the control and the three treatments. However, appearance, odour, texture, and purchasing intension were significantly different ($P<0.05$) among the different yogurt samples. The Treatment 1 (i.e. 10% jackfruit pulp) exhibited the best scores for most of those attributes. Treatment 1 was the best in appearance and texture with median scores of 3.81. Further, Treatment 1 was the second best in odour with a median of 3.13, while the control was the best with a median of 3.38.

The overall quality of the samples was similar with each sample showing a median of 3.50, however, Treatment 1 showed the highest sum of ranks, leading to the highest purchasing intention score (median score=4.00), while all other types of samples exhibited a median of only 3.00. Also, the sum of ranks for Treatment 1 was 93.5, while that of the control, which was the second best, was only 76.0, indicating the aptness of ripe jackfruit flesh pulp to enhance the sensory qualities of oat powder incorporated yogurt. These results reveal that dual fortified yogurt with excellent sensory attributes can be formulated by incorporating oat powder at a concentration of 3.75% (w/v) and ripe jackfruit pulp at a concentration of 10% (w/v). The mean scores of the different yogurt samples with respect to the sensory attributes are indicated in Figure 1.

Physicochemical Parameters

The physicochemical parameters of yogurt are indicative of the quality and shelf-life of the product. The physicochemical parameters of Treatment 1 (i.e. 10% jackfruit pulp), which was chosen for further analysis, showed a significant variation with time as expected (Table 2).

The pH of the yogurt sample decreased and TA of the yogurt sample increased with time, which could be ascribed to the conversion of lactose into lactic acid, due to bacterial fermentation [29]. The pH values were in acceptable range up to 12 - 15 days and TA values were acceptable up to 18 days [28]. TSS decreased with time possibly due to the consumption of soluble material by bacteria during fermentation.

The variation of syneresis, which indicates the extent of whey separation, with time was determined as a quality parameter. Although syneresis of regular yogurt gradually increases with time most probably due to the rearrangement of the casein network [30], syneresis of Treatment 1 significantly decreased with storage time (Table 3). Treatment 1 contained a higher fibre and TS level that can hold water, due to the incorporation of jackfruit pulp and oat powder. In addition, the interactions of increased fibre and total solids with whey protein and changing casein network would have caused the decrement of syneresis with time, of Treatment 1. In fact, the incorporation of β-glucan, which is the major fibre component of oats and incorporation of fruit material such as apple pomace have reduced

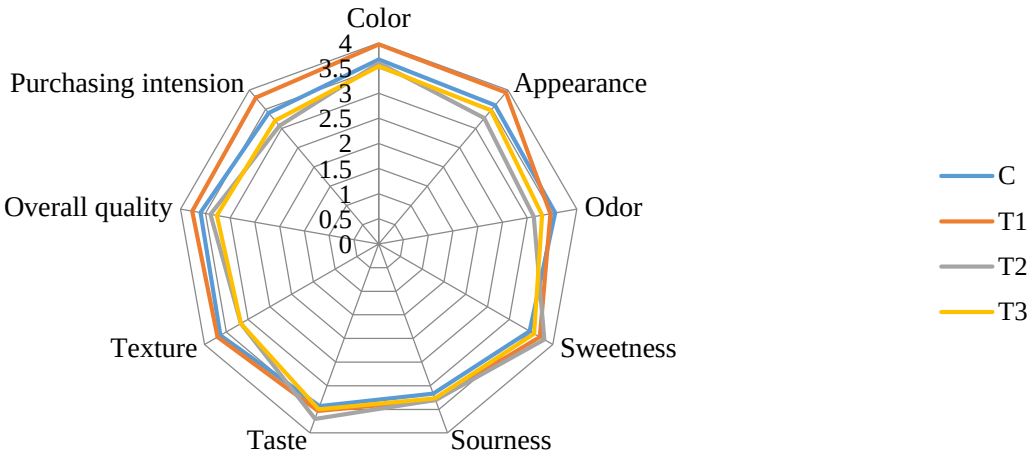

Figure 1: Mean Scores of Different Yogurt Samples for Sensory Attributes
Note: C: Control (no jackfruit pulp), T1: Jackfruit pulp 10%, T2: Jackfruit pulp 20%, T3: Jackfruit pulp 30%

Table 2: Variation of Physicochemical Properties of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Set Yogurt with Time

Time Period (Days)	pH	TA (%)	TSS (%)
Initial	$4.6^{a} \pm 0.01$	$0.8^{e} \pm 0.00$	$28.1^{a} \pm 0.33$
3	$4.6^{b} \pm 0.00$	$0.8^{e} \pm 0.03$	$26.5^{ab} \pm 0.33$
6	$4.5^{c} \pm 0.01$	$0.9^{ed} \pm 0.00$	$25.5^{bc} \pm 0.33$
9	$4.5^{d} \pm 0.01$	$1.0^{cd} \pm 0.06$	$24.3^{d} \pm 0.29$
12	$4.5^{e} \pm 0.01$	$1.0^{c} \pm 0.03$	$23.5^{de} \pm 0.33$
15	$4.5^{f} \pm 0.00$	$1.1^{cb} \pm 0.03$	$22.5^{e} \pm 0.33$
18	$4.4^{g} \pm 0.00$	$1.1^{b} \pm 0.03$	$21.1^{f} \pm 0.33$
21	$4.3^{h} \pm 0.00$	$1.3^{a} \pm 0.03$	$20.5^{f} \pm 0.33$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level. TA: Titratable Acidity, TSS: Total Soluble Solids.

syneresis of yogurt [31-32]. Favourably, the firmness of Treatment 1, which is the jackfruit pulp (10% w/v) and oat (3.75% w/v) incorporated yogurt, remained constant up to day 21 (Table 3).

Proximate Analysis

Proximate analysis results of the selected jackfruit pulp (10% w/v) and oat (3.75% w/v) incorporated yogurt (T1) were compared with that of a representative market yogurt, in order to evaluate the content of basic food components. Table 4 gives the proximate composition of the yogurt developed in this study and 'market yogurt'.

Table 3: Variation of Syneresis and Texture (firmness) of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt with Time

Time (Days)	Syneresis (%)	Texture or Firmness (N)
Initial	$6.9^{a} \pm 0.07$	$0.12^{a} \pm 0.01$
7	$4.9^{b} \pm 0.24$	$0.66^{a} \pm 0.28$
14	$3.3^{c} \pm 0.06$	$0.15^{a} \pm 0.09$
21	$2.2^{d} \pm 0.16$	$0.06^{a} \pm 0.01$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level.

Table 4: Variation of Proximate Parameters of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt and Market Yogurt

Proximate Component	Market Yogurt	Jackfruit Pulp and Oat Incorporated Yogurt
MC%	$70.7^{a} \pm 0.47$	$70.8^{a} \pm 0.12$
TS%	$31.0^{b} \pm 0.30$	$35.8^{a} \pm 0.71$
Ash%	$0.1^{b} \pm 0.03$	$0.5^{a} \pm 0.03$
Protein%	$2.9^{b} \pm 0.01$	$5.9^{a} \pm 0.06$
Fat%	$3.0^{b} \pm 0.06$	$4.0^{a} \pm 0.12$
SNF%	$31.3^{b} \pm 0.18$	$40.4^{a} \pm 0.48$
Fibre%	$0.0^{b} \pm 0.00$	$1.0^{a} \pm 0.03$
Carbohydrate%	$23.3^{a} \pm 0.49$	$18.0^{b} \pm 0.19$

Note: Values with different superscript letters in each column denote significant differences at 0.05 significance level.

Although the moisture content of T1 was higher than that of the market yogurt, the increase was only 0.1%, which indicates that the moisture content of T1 is at an acceptable level. As expected, T1 showed a higher mean value for TS (35.8%), than the market yogurt which showed a value of 31.0%. It is due to the incorporation of jackfruit and oats. Also, the high mineral content of jackfruit pulp and oats, which is beneficial for human health, resulted in a significantly higher ash content of T1 (0.5%) than the market yogurt (0.1%).

The protein content of T1 (5.9%) was significantly higher than that of the market yogurt (2.93%), due to the addition of jackfruit and oats rich in proteins [12, 23] in the T1 formulation. Also, the fat content of T1 (4.0%) was significantly higher than that of the market yogurt (3.0%) as, incorporation of oats in T1 is a good source of fat [12]. Further, the fat content of T1 is above the minimum level of fat content required for yogurt [28]. This is a favourable and essential factor as fat contributes to building the microstructure of yogurt.

The two yogurt samples showed significantly different solid-non-fat (SNF) contents. The SNF value of T1 (40.4%) was significantly higher than that of the market yogurt (31.3%), due to the incorporation of oats, especially rich in fibre, and jackfruit pulp in T1. SNF of regular yogurt mainly contains carbohydrate, lactose, protein and mineral matter [33] and the SNF value should be at least 8% [28]. This value may be raised in order to achieve the appropriate texture and viscosity of the final product [34]. The high score for texture exhibited by T1 according to the sensory evaluation may be because of the high SNF value of T1. In addition, the fibre content contributing to SNF content of T1 may give functional properties to the developed yogurt as described previously. In fact, the fibre content of T1 was significantly higher than that of the market yogurt.

Although T1 consisted of higher percentages of protein, fat, fibre and ash, the market yogurt consisted of a significantly higher percentage of carbohydrates than T1, indicating the suitability of T1 for low carbohydrate diets. Nevertheless, T1 and market yogurt showed comparable energy values approximating to 130 kCal/100g, indicating the appropriateness of T1 for obtaining energy through consumption.

Microbial Safety Evaluation of Jackfruit Pulp (10% w/v) and Oat (3.75% w/v) Incorporated Yogurt

Microbial spoilage which leads to the development of unfavourable sensory attributes, undesirable physicochemical changes and toxins, and growth of pathogens, may result in food products unfit for consumption. Thus, the microbial safety of the developed yogurt product was assessed using the total plate count and yeast and

mould count. The bacterial count showed a steep increase up to the seventh day, after which it showed a slow increase up to the 14th day (Table 5). The bacterial count reduced after the 14th day as indicated by the plate count on the 21th day, due to the spoilage of the yogurt sample, mainly due to the increment of acidity which retards the bacterial growth in yogurt [33].

The yeast and mould count increased with time. The development of high acidity and low oxygen conditions during the fermentation process may offer favourable conditions for the growth of yeasts and moulds of which contamination takes place mainly due to the processing environment [35]. This result indicates that ripe jackfruit pulp (10% w/v) and oat powder (3.75% w/v) incorporated yogurt is more suitable for consumption within 14 days from the day of production at the preservative (potassium sorbate) level of 300 ppm. However, the preservative level could be increased up to 1000 ppm according to the Codex Standard [36] for increasing the shelf life of yogurt.

Table 5: Variation of Total Plate Count and Yeast and Mould Count of Jackfruit Pulp (10% w/v) and Oat (3.75 % w/v) Incorporated Yogurt

Storage Period (days)	Total Plate Count (CFU/g)	Yeast and Mould Count (CFU/g)
Initial	7.9×10^4	-
7	3.5×10^5	2.35×10^2
14	5.2×10^5	2.82×10^3
21	6.2×10^4	3.12×10^3

CONCLUSION

A consumer preferable functional yogurt, dual fortified with oat powder and ripe jackfruit pulp, was developed using 3.75% w/v oat powder and 10% w/v jackfruit pulp contents. It was, also, observed that properly packaged jackfruit flavoured oat incorporated yogurt can be stored at 4 -8 °C up to 14 days with a minimum level of preservative (300 ppm of potassium sorbate). The nutrient content, especially protein and fat along with fibre, of this developed yogurt was higher than that of a representative regular yogurt from the market. This product may be constituted as a fermented diary based food product with favourable sensory properties and acceptable shelf life, offering much health benefits to the consumers.

CONFLICT OF INTEREST

The authors would like to declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

UR: Investigation and data curation. GP: Designed the research, supervised the study, performed statistical analysis and wrote the manuscript. AW: Designed the research and supervised the study.

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