Research Article

Physicochemical, Textural and Sensory Properties of Cottage Cheese Enriched with Jackfruit Seed (*Artocarpus heterophyllus*) Powder

K.G.T.S.D. Bandara and K.M.G.M.M. Kariyawasam*

**menaka.k@uwu.ac.lk*

Department of Biosystems Technology, Faculty of Technological Studies, Uva Wellassa University, Badulla, 90000, Sri Lanka

Abstract

The application of Jackfruit seed powder in convenience foods could boost the commercial value of Jackfruit seeds while also helping to meet the population's protein needs. The objective of the present study was to evaluate the feasibility of fortifying cheese with jackfruit seed powder to improve its nutritional, functional, and sensory characteristics. Experimental cottage cheese samples were prepared with whole milk supplemented with 1%, 1.5% and 2% jackfruit seed powder (JSP). The products were stored at 4℃ for three weeks. Based on the sensory results, the cottage cheese sample with 1.5% jackfruit seed powder (JS_2) was chosen as the best level for cottage cheese preparation, which had the highest textural, flavor and overall acceptability scores. The addition of jackfruit seed powder to cheese samples greatly improves the protein content (25.73±0.05%) while having no effect on the ash or fat content. There was no significant difference in antioxidant activity of JS_2 at 7 days of refrigerated storage, while value was comparable to the control sample (67.79±3.66%). Moreover, the products were analyzed for textural properties and there was no significant difference in hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness when compared to the control sample. These findings confirmed that adding jackfruit seed powder to cottage cheese can enhance its protein content while increasing sensory attributes, implying that it has the potential to be employed as a protein supplement in the dairy sector.

Keywords: *Antioxidant activity, cottage cheese, jackfruit seed powder, protein enrichment, value addition*

1. Introduction

Cottage cheese is a fresh, un-ripened cheese produced through milk coagulation that has a high moisture content, a mild acidic flavor, a smooth texture, and a short shelf life (Hubbard, Jervis and Drake, 2016). It is available in many parts of the world and is enjoyed by people of all ages, including children, young adults, and those aged 55 and over (Davis *et al.*, 2010). Cottage cheese is a high-protein, casein-rich food that is also high in calcium and salt, both of which are helpful to bone and dental health (Khatun *et al.*, 2019). Nonetheless, cottage cheese is not a high-energy diet; therefore, it is widely consumed by those who want to boost their high-quality protein intake through whole food consumption (Pozzobon and Pozzobon, 2019). Furthermore, cottage cheese contains bioavailable vitamin D and D3, making calcium fixation easier, therefore women tend to consume cottage cheese to build up calcium storage to fight osteoporosis (Crevier *et al.*, 2017; Pozzobon and Pozzobon, 2019). Despite the foregoing health benefits, cheese consumption is minimal due to high pricing and limited production in developing nations such as Sri Lanka (Ibrahim, 1999). Therefore, adding value to cottage cheese using locally accessible sources can thereby increase cottage cheese consumption in developing nations.

The world's largest edible fruit is the jackfruit (*Artocarpus heterophyllus*). It is a high-nutritional tropical fruit. Although jackfruit seeds are not generally consumed as a vegetable, some people consume them after boiling or roasting (Mandave, Bobade and Patil, 2018). Jackfruit seed has a high starch content, which aids blood sugar regulation and digestive health (Burkill, 1997). Furthermore, jackfruit seeds contain carbohydrates (37.4 - 42.5%), protein (5.3 - 6.8%), and fiber (1.5%). These seeds are also high in zinc, iron, calcium, copper, potassium, and manganese (Jagtap, Panaskar and Bapat, 2010). Jackfruit seeds have a variety of therapeutic and functional properties, including antioxidants (due to high levels of thiamine and riboflavin) (Lumbantobing, Tanardi and Putra, 2020), anti-inflammatory, anti-cariogenic, antifungal, and antibacterial effects (Ranasinghe, Maduwanthi and Marapana, 2019).

Malnutrition in developing nations is reportedly caused by inadequate protein consumption. Additionally, it has been noted that the economic crisis in Sri Lanka has contributed to an increase in child malnutrition (Central Bank of Sri Lanka, 2022). In order to solve this problem, it is crucial to evaluate new, affordable protein sources. One of the greatest approaches in this regard would be to use jackfruit seeds as a protein-rich supplementary food source (Sultana, 2017). Despite having a high nutritional content, jackfruit seeds are frequently thrown away each year due to a lack of knowledge about their advantages in terms of nutrition and wellbeing (Ranasinghe, Maduwanthi and Marapana, 2019). Its market value is therefore low both in Sri Lanka and beyond. Although several studies have been conducted to evaluate the potential use of jackfruit seed flour in the bakery and confectionery industries (Waghmare *et al.*, 2019), no studies have been conducted to demonstrate the feasibility of using jackfruit seed flour as a protein enriching agent in dairy products. Therefore, the purpose of this study was to investigate the feasibility of employing jackfruit seed powder as a protein enrichment agent in cottage cheese and evaluate the characteristics of resulting cheese and the consumer acceptability.

2. Materials and Methods

2.1. Preparation of jackfruit seed powder

The jackfruit seed powder (JSP) was prepared as the method of (Verma, Mishra and Dubey, 2020) with slight modifications. Briefly, the jackfruit seeds were soaked overnight, and the white aril and brown coat layer was removed. Seeds were thoroughly washed, thawed to remove excess moisture, and cut into pieces and then oven (GX125B, China) dried at 50℃ for 48 h. The chips were grounded into fine powder and sieved using 150 µm mesh sieve. Powder was sealed in glass jar and stored in a refrigerator (4±1C°) for further use.

2.2. FTIR spectral analysis of the jackfruit seed powder

The specific functional groups in the JSP were characterized by Fourier transform infrared spectroscopy (FTIR) (ALPHA, Germany). Spectrum was recorded in the absorption range between 450-4000 cm^{-1} at a resolution of 4 cm^{-1}.

2.3. Preparation of cottage cheese

Commercially available pasteurized full cream fresh milk (Kothmale Full Cream Fresh Milk, Sri Lanka) was used for cheese preparation. Cheese was prepared according to Kariyawasam *et al.* (2019) with some modifications. The JSP added fresh milk was heated in an autoclave (BKQ Z501, China) at 85℃ for 20 minutes and then cooled down to 37℃. The starter culture (STI-12, Thermophilic culture, Denmark) and rennet (CHY-MAX Powder Extra NB, Denmark, 1g/1L) were added. Once curd was formed, it was cut into 1 cm^3 cubes, and the whey was removed. The cubes were then washed with 4℃ water and pressed. The control cheese sample was prepared without adding JSP following the same procedure. Four types of cheese samples were prepared and labeled as follows: control cheese as CC, Jackfruit seed powder added cheese as JS_1 (1% JSP), JS_2 (1.5% JSP) JS_3 (2% JSP). Cheese samples were then vacuum packed and stored at refrigerator (4±1C°). The optimum proportions of jackfruit powder to be incorporated into cottage cheese were determined through preliminary investigations involving sensory analysis and physicochemical testing.

2.4. Sensory evaluation

Sensory evaluation of cheese samples was conducted by semi-trained panel of 30 members using 5-point hedonic scale: 5- highly acceptable, 1- not acceptable. During the sensory evaluation, the following sensory qualities were evaluated: aroma, color, appearance, taste and overall acceptability in accordance with the International Organization for Standardization guidelines (ISO 6658:2017).

2.5. Compositional and chemical analysis of cottage cheese samples

Cheese samples and jackfruit seed powder were analyzed for crude protein, crude fat, moisture, and ash after 7 days of refrigerated storage. Crude protein was analyzed by Kjedhal method (AOAC, 991.02) and fat content was analyzed by Gerber method (AOAC, 2000.18). Moisture content was measured using a moisture analyzer (MA 110.R, Poland). Ash content was obtained by heating appropriate weights of samples in a muffle furnace at 550°C overnight. The pH of cheese samples was measured using a digital pH meter (MM.42DP, Japan). The titratable acidity of the samples was determined by titrating the samples against sodium hydroxide (0.1 N) using phenolphthalein as an indicator.

2.6. Antioxidant activity

Water soluble extracts of cheese samples was prepared to determine the antioxidant activity as the method described by (Kariyawasam, Lee and Paik, 2023) with some modifications. Briefly, 10 g of cheese samples were measured using an analytical balance (PS-510 R1, Poland) and dissolved in 30 mL of distilled water and mixed well using vortex mixer (F202A0176, Italy) until cheese get fully dissolved. The samples were transferred (approximately 2 mL) into Eppendorf tubes and centrifuged using centrifuge machine (Legend micro 17R, Germany) at 14,000×g at 4℃ for 30 minutes. Subsequently, the uppermost layer of the centrifuged sample was removed, and supernatant was used for further analysis.

The antioxidant activity of 7 days old samples was determined according to (Kariyawasam *et al.*, 2019). Two hundred microliters of WSE were added using micropipette into Eppendorf tubes and 1 mL of freshly prepared 100 µM 2, 2-diphenyl-2-picrylhydrazyl radical (DPPH) was added and allowed to stand in the dark for 15 to 20 min. Absorbance was measured by spectrophotometer (Eppendorf Bio spectrometer fluorescence 6137KG005002, Germany) at 517 nm. Three replicates were carried out for each sample. The results were expressed as percentage of scavenging activity, which was calculated as follows:

DPPH radical scavenging activity (%) = [A control – A sample / A control] × 100%

A control and A sample represent the absorbance of the control (distilled water) and WSE of the cottage cheese samples, respectively.

2.7. Texture profile analysis

The texture of the cheese samples was analyzed using texture analyzer (TexturePro CT3, Canada) according to the method described by (Uprit and Mishra, 2007) just after the production. The hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness of the cheese samples were measured.

2.8. Evaluation of shelf life of cottage cheese samples

The analysis of the shelf life of cottage cheese samples was conducted by packing 25.0 g of each sample in aluminum foil, followed by vacuum sealing in high density polyethylene (HDPE) bags and storage in a refrigerator (4±1°C). Each sample was appropriately labeled before storage. Analyses were performed on each sample after 0, 7, 14, and 21days. The pH value, titratable acidity, and organoleptic properties of the cheese samples were measured during the shelf-life analysis.

2.9. Microbiological analysis of cottage cheese samples

Total viable count (cfu g^{-1}), and total yeast and mold count (cfu g^{-1}) of the cottage cheese samples were determined as method described by Kariyawasam *et al.* (2019) after 14 days of refrigerated storage.

2.10. Statistical data analysis

Statistical analysis was carried out using SPSS Statistics 25 (IBM, USA). The data were assessed using one-way analysis of variance (ANOVA) or T- test (simple comparison between two means) with statistical significance was determined at 5% significance level ($P < 0.05$).

3. Results and Discussion

3.1. FTIR spectral analysis of the jackfruit seed powder

Figure 1 shows the FTIR spectra of jackfruit seed powder. The following functional groups were identified in the FTIR spectra of JSP. The peaks at 3266 cm^{-1} are due to the moisture content of the powder. The band 1636 cm^{-1} is due to free carboxyl groups in pectin. Furthermore, peaks between 1000 cm^{-1} and 1350 cm^{-1} are commonly detected in conjunction with pectin (a polysaccharide with various degrees of esterification) (Bayu *et al.*, 2019). Additionally, the bands below 1200 cm-1 in the spectra correspond to the carbohydrate fingerprint region, particularly polysaccharides, which may involve linkages (R-O-R) or cyclic C-C bonds. The findings of the current study align with those reported by Chandran (2017). Waghmare *et al*., (2019) also reported FTIR spectrum of jackfruit seed powder. According to that report, the peaks of the amines, amides, and amino acids, indicate the presence of protein. Moreover, absorption bands show the presence of biomolecules such as carbohydrates, polysaccharides, and lipids. The aromatic compounds indicate the existence of flavonoids, and it showed presence of Sulphur and its derivatives, contributing to the antimicrobial activity of JSP.

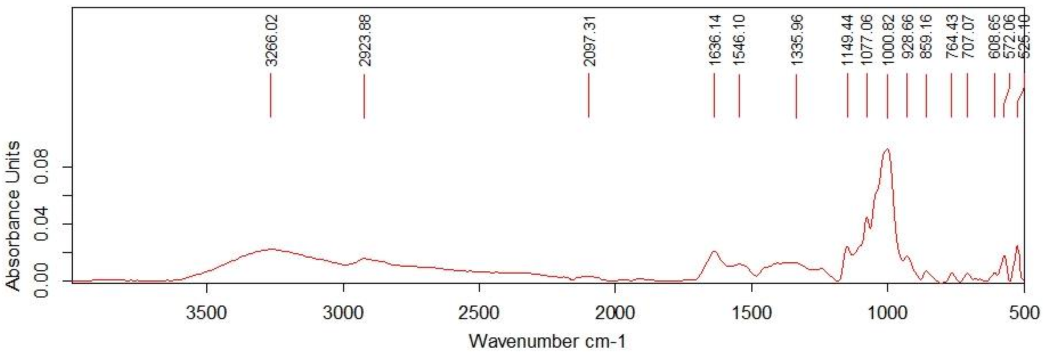

Figure 1: FTIR analysis of jackfruit seed powder

3.2. Sensory evaluation

Table 1 demonstrated the sensory attributes of jackfruit seed powder added cottage cheese samples. The addition of jackfruit seed powder did not have a significant effect on colour and odour of the cottage cheese samples. However, the addition of jackfruit seed powder significantly affects the texture, flavour and overall acceptability of the cheese samples. The highest textural scores were observed in JS_3 (3.87 ± 1.01) followed by JS_2 (3.67 ± 0.81) and the lowest in the control (3.41 ± 1.0) sample. The JS_2 sample had the highest flavour score of 3.89 ± 0.97; nevertheless, increasing the level of JSP negatively affected the flavour attribute. Overall acceptability of 1.5% jackfruit seed powder treated cottage cheese was significantly higher than all other cheese samples ($p < 0.05$). Therefore, it is clear that 1.5% jackfruit seed powder added samples has the highest sensory scores.

Table 1: Sensory scores of cottage cheese samples

Sample	Color	Texture	Flavor	Odor	Overall acceptability
CC	3.51 ± 0.57^a	3.41 ± 1.0^a	3.68 ± 0.57^a	3.30 ± 1.18^a	3.40 ± 1.14^a
JS_1	3.53 ± 1.20^a	3.43 ± 1.18^a	3.62 ± 0.87^a	3.37 ± 0.81^a	3.48 ± 1.07^a
JS_2	3.50 ± 0.81^a	3.67 ± 0.81^b	3.89 ± 0.97^b	3.47 ± 1.01^a	3.77 ± 0.81^b
JS_3	3.47 ± 1.01^a	3.27 ± 1.01^c	2.99 ± 1.02^c	3.20 ± 0.96^a	2.86 ± 1.03^c

$^{a-c}$ Means within a coloumn with different superscripts differ ($p < 0.05$)
All values are means of 3 replicates (mean ± SD)
CC= control cottage cheese, $JS_{1=}$ 1.0% jackfruit seed flour added cottage cheese sample, JS_2= 1.5% jackfruit seed flour added cottage cheese sample JS_3= 2.0% jackfruit seed flour added cottage cheese sample

3.4. Compositional and chemical analysis of cottage cheese samples

The compositional data of control sample and JS_2 after 7 days of refrigerated storage are shown in the Table 2. The addition of jackfruit seed powder had no discernible influence on ash or fat content. However, JSP treated samples had a higher moisture content (66.47±0.02%, $p < 0.05$) than the control (24.87±0.03%). The addition of JSP may have contributed to the elevated moisture levels in JS_2. Additionally, a significant ($p < 0.05$) increase in protein (25.73±0.05%) was found in the JS_2 sample. This shows that the high protein content of JSP contributed to an increase in protein content, implying that JSP might be used as a protein enriching agent in dairy products. This finding is concurred with Ahmed *et al.* (2020) and Lumbantobing, Tanardi and Putra (2020) who also reported increase in protein content in yoghurt prepared with jackfruit seed powder as a substitute for skim milk and vegan ice cream developed with jackfruit seed-based milk, respectively.

Table 2: Compositional data of cottage cheese samples after 7 days of refrigerated storage

Parameter	Cottage cheese samples	
	CC	JS_2
Moisture (%)	$24.87±0.03^{b}$	$66.47±0.02^{a}$
Crude protein (%)	$22.73±0.11^{b}$	$25.73±0.05^{a}$
Crude fat (%)	$19.33±0.57^{a}$	$18.33±0.57^{a}$
Ash (%)	$1.46±0.06^{a}$	$1.41±0.092^{a}$
pH	$4.52±0.06^{b}$	$4.42±0.10^{a}$
Titratable acidity (%)	$1.68±0.33^{b}$	$1.81±0.28^{a}$

$^{a\text{-}b}$ Means within a row with different superscripts differ ($p < 0.05$)
All values are means of 3 replicates (mean ± SD)
CC= control cottage cheese, JS_2= 1.5% jackfruit seed flour added cottage cheese sample

However, JSP supplementation significantly decreased the pH of the experimental sample during refrigerated storage, indicating a faster rate of acid generation than the control cheese sample. The higher viability of starter cultures in JSP-enriched sample could have led to elevated acid production. Furthermore, because JSP is abundant in carbohydrates, it may act as a nutrition source for better growth of starter organisms in JS_2 sample. Thus, the addition of JSP increased the survival and metabolic activities of starter cultures. The enhanced titratable acidity ($p < 0.05$) in the JS_2 sample is also related to the increased metabolic activity of starter cultures.

The jackfruit seed powder had 16.01±0.01% protein, 2.38±0.04% fat 0.97±0.01% ash and 7.03±0.41% moisture. Sultana (2017) also reported 16.01% protein content in jackfruit seed powder, which was similar to the values found in this study.

3.5. Antioxidant activity of cottage cheese

The antioxidant activity of control sample (CC) and 1.5 % jackfruit seed powder added sample (JS_2) were 66.15±3.74% and 67.79±3.66%, respectively after 7 days of refrigerated storage. However, there was no significant difference in antioxidant activity (p >0.05) between the two cheese samples. According to Chandran (2017), jackfruit seeds have significant antioxidant activity due to their high hydroxyl group concentration, which is proportionate to their phenolic content. Moreover, the study conducted by Sreeja Devi, Kumar and Sabu (2021) also reported that jackfruit seeds have antioxidant activity due to its phenolic and flavonoids contents. However, the absence of significant levels of antioxidants in the current study could be attributed to the use of small quantity of jackfruit seed powder (1.5%).

3.6. Textural analysis of cottage cheese

The results of textural properties of cottage cheese samples are shown in Table 3. According to the results, supplementation of JSP increased hardness (91.00±5.20 g), adhesiveness (3.77±1.07 mj), springiness (12.95±0.21 mm), gumminess (46.67±8.50 g) and chewiness (5.97±1.10 mj). However, the values were not significantly different from the control cheese sample ($p > 0.05$). Thus, the results revealed that JSP can be added to the cheese samples without compromising the textural characteristics of the cottage cheese.

Table 3: Textural properties of cottage cheese samples

Textural property	Cottage cheese samples	
	CC	JS_2
Hardness (g)	53.7±14.2[a]	91.00±5.20[a]
Adhesiveness (mj)	2.20±0.26[a]	3.77±1.07[a]
Cohesiveness	0.57±0.12[a]	0.50±0.07[a]
Springiness (mm)	12.81±0.36[a]	12.95±0.21[a]
Gumminess (g)	29.67±5.77[a]	46.67±8.50[a]
Chewiness (mj)	3.76±0.76[a]	5.97±1.10[a]

[a] Means within a row with different superscripts differ ($p < 0.05$)
All values are means of 3 replicates (mean ± SD)
CC= control cottage cheese, JS_2= 1.5% jackfruit seed flour added cottage cheese sample

3.7. Evaluation of shelf life of cottage cheese samples

The results shown in Figure 2 illustrate the variations in pH and titratable acidity of cheese samples during the storage period. The initial pH value of the control sample was 4.57±0.01, and the sample with 1.5% JSP added had an initial pH of 4.56±0.02. The pH values of both samples gradually decreased during the storage period. After 21 days of storage, the final pH value for the control was 4.43±0.02, and JS_2 pH was 4.29±0.04 (p < 0.05). This post-acidification may be attributed to the residual activities of starter cultures and the production of organic acids. The high post-acidification in JS_2 may be linked to the high carbohydrate content of the cottage cheese sample, potentially enhancing the growth of the starter culture. The titratable acidity of the cottage cheese samples showed a continuous increase during storage. Our results are aligned with Ahmed et al. (2020), who observed a decrease in pH and an increase in acidity in yogurt supplemented with jackfruit seed flour. Furthermore, the increase in titratable acidity over the storage period suggests a rise in the number of acid-generating bacteria (Ali *et al.*, 2022).

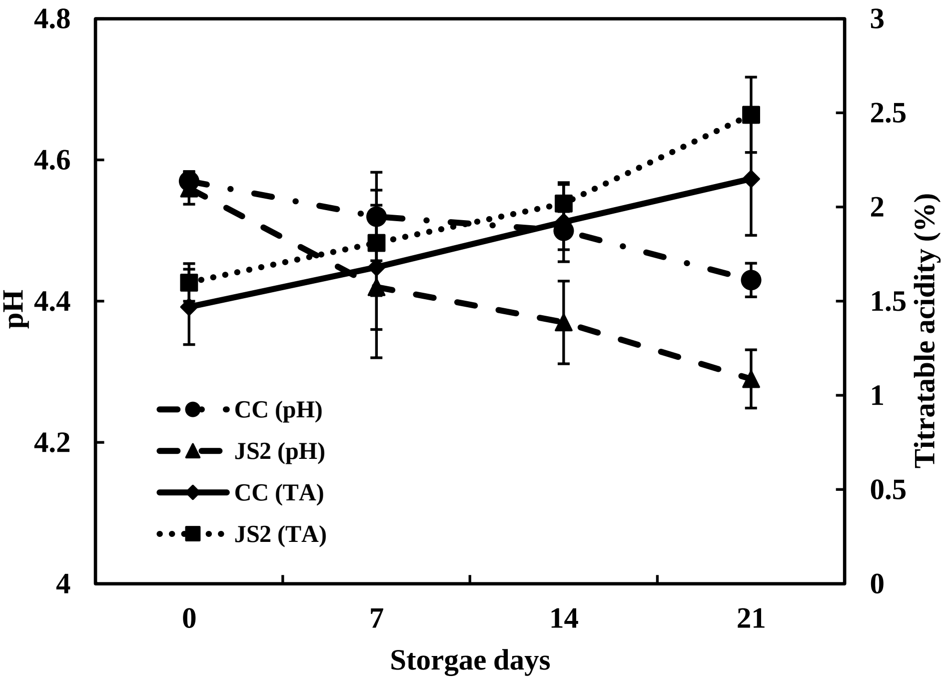

Figure 2: Titratable acidity and pH during storage at 4 °C for 21 days
All values are means of 3 replicates (mean ± SD).
CC= control cottage cheese, JS2= 1.5% jackfruit seed flour added cottage cheese sample.

Additionally, organoleptic properties such as color, odor, and consistency of JS_2 changed starting from the 14 days of the storage period. Therefore, the shelf life of the cottage cheese samples was determined to be 14 days. Khaliq *et al*. (2021) stated that cottage cheese, being a high-moisture cheese, has a limited shelf life of 10 days even when stored at 4°C.

3.8. Microbiological analysis of cottage cheese samples

Total viable count was higher in the control sample (4.01±0.02) than that of the 1.5% jackfruit seed powder added sample (3.35±0.01). According to results there was no significant difference (p > 0.05) between two samples. Chandran (2017) stated that jackfruit seed has potential antibacterial effects on *S. aureus, E. coli* and *Klebsiella*. So, the lower plate count on treatment sample (JS2) could be due to antibacterial effects of jackfruit seed powder which was added to cottage cheese. However, the yeast and mold count were absent in both samples. Several studies including Trindade *et al.* (2006); Ranasinghe, Maduwanthi and Marapana (2019) stated about the antifungal activity of jackfruit seed powder. This could be attributed to the absence of yeast and mold count in cottage cheese samples.

4. Conclusions

This study explored the impact of adding jackfruit seed powder at various ratios on the sensory, proximate, physicochemical, texture, and shelf life of cottage cheese samples. The sensory analysis revealed that incorporating 1.5% of JSP resulted in the highest flavor and overall acceptability, with no significant changes observed in color and odor of the cheese samples. Furthermore, the addition of jackfruit seed powder did not affect ash or fat content but notably increased the protein content of the cheese samples, suggesting its potential use as a protein supplement in the dairy industry. However, the inclusion of JSP resulted in post-acidification, and alterations in sensory attributes after 14 days of storage, thus the shelf life of the cottage cheese samples is 14 days at refrigerated storage. Despite these observations, JSP addition had no significant impact on the antioxidant activity of cottage cheese samples. Furthermore, incorporating 1.5% of JSP did not adversely affect the textural properties, including hardness, adhesiveness, springiness, gumminess, and chewiness. Therefore, this study emphasizes the possibility of adding value to jackfruit seed powder by employing it as a protein supplement in convenience foods such as cheese, while providing nutritional benefits to the consumer.

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