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Research Article

Chemical Properties and Textural Analysis of Synbiotic Cheese with Konjac Flour and *Lactobacillus rhamnosus* During Storage

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Abstract | The development of synbiotic cheese as a functional food addresses growing consumer demand for health-oriented products. This study aimed to evaluate the chemical properties and texture profile of synbiotic cheese made with konjac flour and *Lactobacillus rhamnosus* during storage. A total of 72 liters of cow milk was processed using a high-temperature short-time pasteurization method and treated with four formulations: control (P0: no additives), konjac flour (P1: 0.03%), *L. rhamnosus* (P2: 5%), and their combination (P3: 0.03% + 5%). Using a 4x3 factorial design with three replicates, cheese samples were stored at 4°C and analyzed at 0, 7, and 14 days using ANOVA and Duncan's test. Results showed significant interactions between treatments and storage duration ($P<0.05$) for moisture, protein total solids, and texture attributes. Konjac flour increased total solids and enhanced fermentation, while *L. rhamnosus* improved protein stability and cohesion. Combined treatment (P3) demonstrated optimal moisture retention, reduced hardness, and improved springiness and gumminess ($P<0.05$), resulting in superior texture throughout storage. P3 also mitigated storage-induced degradation compared to control. The findings highlight the synergistic benefits of konjac flour and *L. rhamnosus* in maintaining chemical and textural stability, contributing to the development of high-quality synbiotic cheese with functional benefits. Future research should explore long-term storage effects and additional strains to optimize product formulations.

Keywords | Cheese, Chemical properties, Functional food, Flour, *Lactobacillus rhamnosus*, Texture stability

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INTRODUCTION

The increasing prevalence of degenerative diseases has increased public awareness of health, driving changes in lifestyle and food consumption (Juniawati *et al*., 2015). As a result, there has been significant progress in the development of functional foods, driven by an increasing consumer focus on healthier dietary choices (Fadhlurrohman *et al*., 2023). Functional foods are those that provide essential nutrients and offer additional health benefits, potentially aiding in the prevention of various diseases, due to their active components (Manzi *et al*., 2007; Fadhlurrohman *et al*., 2023). Among these foods, cheese, demonstrates considerable promise as a functional food.

The basic ingredient of cheese is sourced from dairy animals. Cow milk-based cheese typically contains

24.92-25.51% protein and 29.83-30.58% fat (Murtaza *et al*., 2008), while goat milk-based cheese contains 12.42-13.52% protein and 22.23-22.87% fat (Muñoz-Bas *et al*., 2024). These nutritional differences suggest that cow milk-based cheese may be more beneficial for health and offers the advantage of being more affordable than goat milk-based cheese. Additionally, cheese can be further enhanced with beneficial microorganisms, such as probiotics, or fortified with bioactive compounds like prebiotics. A cheese combining both probiotic and prebiotic refers to as synbiotic cheese (Markowiak and Ślizewska, 2017). Synbiotic cheese offers the dual benefits of probiotics, which are known to improve gut health, and prebiotics, which support the growth and activity of beneficial gut microorganisms (Bakhtiyari *et al*., 2024).

The International Scientific Association for Probiotics and Prebiotics (ISAPP) defines prebiotics as selectively fermented ingredients that beneficially affect the host by stimulating the growth or activity of beneficial bacteria in gastrointestinal tract (GIT) (Gibson *et al*., 2017). Typically, prebiotics are short-chain carbohydrates, such as oligosaccharides, that human digestive enzymes cannot break down, thus allowing them to reach the colon where they promote the growth of beneficial gut microbiota (Mohanty *et al*., 2018). Probiotics, on the other hand, are live microorganisms that confer health benefits to the host when administered in sufficient quantities, typically measured in 10^5 to 10^7 CFUs/ml. The synergistic combination of probiotics and prebiotics is referred to as synbiotics, which can be incorporated into various food products, including cheese (Latif *et al*., 2023).

One promising source of prebiotics is konjac flour, which contains glucomannan, a water-soluble polysaccharide known for its health benefits and use in food formulations (Budiastra and Noviyanti, 2023). Konjac flour is a powder obtained from the tubers of the konjac plant, primarily composed of glucomannan, a soluble fiber that can make up to 65% of its content (Anam *et al*., 2024). The glucomannan in konjac flour modulate the digestive system through its interaction with various polysaccharides, including galactomannan and glucan, which can positively influence gut health (Zhang *et al*., 2020; Kavas *et al*., 2021). Additionally, it has been reported that supplementing 0.5% of commercial konjac glucomannan can enhance textural properties of cheese by increasing its hardness (da Silva *et al*., 2016), attributed to its water holding capacity, which creates a more compact structure (Liu *et al*., 2008). Akesowan (2016) added, konjac flour with high glucomannan content, is able to absorb water when added to milk, forming gel-like structures that enhances the texture of the cheese. When combined with milk proteins like casein and whey, it strengthens their ability to form firmer, more cohesive gels, resulting in a more stable and improved texture in cheese. In contrast, other studies have shown that the same level of konjac flour (0.5%) negatively affects the texture of Mozzarella cheese, reducing the firmness and increasing stickiness, as well as impacting color and browning while slightly increasing moisture content (Dai *et al*., 2018), which further could negatively influence cheese quality and consumer preferences.

Probiotics, particularly *Lactobacillus rhamnosus* (*L. rhamnosus*), can enhance the effectiveness of konjac flour as a source of prebiotics in cheese production, where *L. rhamnosus* plays a dual role as acidifiers and starters, facilitating fermentation and contributing to the development of desirable flavors and textures (Setyawardani *et al*., 2017). The presence of prebiotics serves as a substrate for the proliferation of probiotics, fostering a symbiotic environment within cheese matrix. Studies have shown that *L. rhamnosus* interact with prebiotic substances such as konjac flour, potentially altering microbial dynamics and improving the functional properties of the cheese over time (Langa *et al*., 2019).

Several studies have highlighted the positive impact of *L. rhamnosus* on cheese quality. It has been shown to improve textural and physiochemical properties of cheese (Prezzi *et al*., 2020), maintain fermentation and the sensory properties of soy cheese (Liu *et al*., 2006), enhance antioxidant activity of cheddar cheese during ripening and simulated gastrointestinal digestion through the formation of small molecular peptides and free amino acids (Liu *et al*., 2018), and significantly improve consumer acceptance (Galli *et al*., 2019). Furthermore, combining 0.03% konjac flour and 5% *L. rhamnosus* has been reported to significantly influence pH, free fatty acid content, and total lactic acid bacteria (LAB), leading to the production of soft cheese with desirable characteristics (Ismiarti *et al*., 2023). However, one of challenges arises during the storage of cheese after production. Storage under cold conditions often induces chemical and structural changes that can impact texture, flavor and overall quality. These changes are influenced by factors such as microbial activity, moisture content, and the presence of added ingredient like prebiotics and probiotics (Shahraki *et al*., 2023; Ismiarti *et al*., 2023). In addition, Rahayu *et al*. (2010) reported that *L. rhamnosus* is proven to be effective in stabilize the quality of goat-milk cheese for 4 weeks of storage, while da Silva *et al*. (2016) observed a stable structure of low-fat cheese using konjac flour. Here, konjac flour serves as a food source for *L. rhamnosus*, promoting its growth and activity (Shori, 2016), which helps maintain a balanced microbial environment in the cheese matrix. This interaction supports the preservation of texture and prevents spoilage, enhancing the cheese stability during storage (Langa *et al*., 2019). Thus, the combination of konjac flour and *L. rhamnosus* is crucial for cheese storage. Additionally, it is anticipated that this combination will promote the growth and activation of microbial metabolism in the gut, ultimately benefiting the host's overall health.

Despite the promising results reported in previous studies, there remains a significant gap in understanding the combined effects of konjac flour and *L. rhamnosus* on cheese properties during storage. While prior research has explored either the individual or combination contributions of konjac flour as a prebiotic and *L. rhamnosus* as a probiotic to cheese formulation, their synergistic interaction and its influence on the chemical properties and texture profile of synbiotic cheese over time are not well-documented. Furthermore, the dynamic changes that occur in functional cheese during storage, particularly those influenced by the integration of these novel ingredients, have not been comprehensively studied. This research, therefore, addresses a critical need to investigate the interplay between konjac flour and *L. rhamnosus* in enhancing the health benefits. In addition, the combination is expected to be able to maintain the quality of synbiotic cheese throughout its storage period. By filling this knowledge gap, the study aims to contribute to the advancement of functional dairy products and offer a valuable insight for the development of innovative cheese formulations with enhanced consumer appeal.

MATERIALS AND METHODS

Time and place of study

The experiment was conducted in June 2023 at Universitas Gadjah Mada, Yogyakarta, Indonesia. The materials used for cheese production included 72 liters of pure cow's milk, with a composition of 2.72% protein, 3.46% fat, 7.44% solid non-fat, and 4.09% lactose, sourced from a smallholder dairy farm in Semarang regency. *Lactobacillus rhamnosus* FNCC 0052 was procured from the Center for Food and Nutrition Studies at Universitas Gadjah Mada, Yogyakarta. Additionally, 21.6 grams of Konjac flour were supplied by a commercial shop in Malang, East Java. Commercial animal rennet and acetic acid were also used in the cheese making process. For the determination of chemical composition, reagents for assessing protein, fat, and lactose levels were employed.

Research design

An experimental study was conducted using a completely randomized design (CRD) with a 4x3 factorial arrangement. The factors included the use of konjac flour and *L. rhamnosus* and storage period (T), with each treatment replicated three times, and each replication repeated twice. The treatments were as follows: no addition of konjac flour and *L. rhamnosus* (P0), addition of 0.03% of konjac flour (P1), addition of 5% *L. rhamnosus* (P2), and addition of 0.03% konjac flour and 5% *L. rhamnosus* (P3). All treatments were stored in a refrigerator at 4° for 0 days (T0), 7 days (T1) and 14 days (T2).

Starter culture preparation

Eighteen grams of skim milk was diluted with distilled water to a final volume of 100 ml and then sterilized at 110 °C for 10 minutes. Subsequently, 100 µL of *L. rhamnosus* from broth culture was pipetted into 100 ml of the sterile skim milk and incubated at 45°C for 18 hours to develop the mother culture. To prepare the starter culture, the mother culture was further diluted in sterile skim milk and incubated under the same conditions as previously described by Ismiarti *et al.* (2023). In this study, LAB viability of all treatments are not measured and it has been reported by Ismiarti *et al.* (2023).

Cheese making

Cheese production followed the methodology outlined by Ismiarti *et al.* (2023). The process began with pasteurizing the milk using a high-temperature short-time (HTST) method at 72°C for 15 seconds, followed by cooling to 45°C. The acidification process involved inoculating the pasteurized milk with a starter culture of *L. rhamnosus* and incubating at 45°C for 2 hours. For the control treatment (P0), acidification was achieved using acetic acid until the pH decreased to 6.1. The subsequent step involved coagulation, where animal rennet (0.06 ml/l) was added and the mixture was allowed to rest for 2 hours to facilitate gelling. To address syneresis, the formed gel was cut into small pieces, and allowed to rest for 10-15 minutes and then filtered using filter cloth. Konjac flour was added according to the treatment protocol, and then cheese was stored in a refrigerator at 4-10°C for 0, 7, and 14 days. Due to equipment limitations, humidity was not recorded in this study, and therefore, humidity recordings are not provided.

Determination of milk composition

The milk composition used as raw material was assessed using a Lactoscan (LactoScan, Milkotronic LTD., Bulgaria). The Lactoscan was positioned in the designated working area, and the power supply was connected to electrical outlet. Upon switching on the power button, the software interface was displayed, indicating that the lactoscan was operational. The device was considered ready for use when the display indicated "Ready to Use". A milk sample was prepared, poured into the analyzer holder, then it inserted into the recess of the analyzer. The analyzer automatically aspirated the milk sample and commenced the measurement process. The result of the analysis was displayed on the monitor and could be printed for the documentation.

Determination of chemical composition

Chemical composition measurements included protein content (determined using Kjeldahl method), moisture content (measured via the thermogravimetric method), ash content, and total solids (following AOAC, 1990).

Determination of texture profile

Texture Profile Analyzer (Stable Micro System, UK) was employed to evaluate the texture profile, including hardness, adhesiveness, resilience, cohesion, springiness, gumminess, and chewiness according to the methods outlined by Peleg (2019) and Astuti *et al.* (2021). Prior to testing, cheese sample was allowed to equilibrate at room temperature for 15 minutes, then cut into the cubes measuring 1x1x1 cm. The texture analysis was performed using a compression mode with a 10 kg load cell.

Statistical analysis

Data were collected and presented as mean ± standard deviation. The data were analyzed using Analysis of Variance (ANOVA) with a Completely Randomized Design (CRD) in a 4x3 factoral arrangement, followed by post-hoc comparisons using Duncan's Multiple Range Test (DMRT). Treatment means differed significantly at $P \leq 0.05$. All statistical analyses were conducted using SAS OnDemand for Academics® (www.sas.com) software.

RESULTS AND DISCUSSION

Chemical properties

The cheese production process involving bacteria, particularly lactic acid bacteria (LAB), alongside the addition of the prebiotics as substrates offers the potential for developing synbiotic cheese with functional benefits for the host. LAB, when classified as probiotics, must fulfil specific criteria: They need to survive the gastrointestinal tract (GIT) by contacting the epithelial cells of small and large intestine and induce lysosomal activation of the epithelial enterocytes (Perdigón *et al*., 2003) and resist pathogenic microorganisms through production of acetic acid, lactic acid, bacteriosins as well as stabilizing the intestinal microflora after long term antibiotics uses (Mazahreh and Ershidat, 2009). Furthermore, LAB should be classified as Generally Recognized as Safe (GRAS) and be deemed safe for human consumption. Chemical composition changes in cheese during storage serve as indicators of ongoing biochemical processes and dehydration (Sumarmono *et al*., 2020). The chemical composition of cheese with incorporation of konjac flour and *L. rhamnosus* is detailed in Table 1.

Table 1: Chemical composition of cheese with the addition of konjac flour and *Lactobacillus rhamnosus* during storage.

Treatments		Moisture	Ash	Total solid	Protein
Interaction between konjac flour, *Lactobacillus rhamnosus*, and storage (days)					
Control (P0)	0 (T0)	44.68 ± 0.35^{b}	3.17 ± 0.26^{b}	55.32 ± 0.35^{f}	22.95 ± 0.62^{b}
	7 (T1)	42.87 ± 0.12^{a}	3.67 ± 0.40^{bc}	57.13 ± 0.12^{g}	21.63 ± 1.54^{b}
	14 (T2)	45.87 ± 1.14^{c}	4.89 ± 0.12^{d}	54.13 ± 1.14^{e}	21.46 ± 0.24^{b}
KF (P1)	0 (T0)	48.85 ± 0.13^{ef}	2.44 ± 0.07^{a}	51.15 ± 0.13^{bc}	22.49 ± 2.05^{b}
	7 (T1)	44.41 ± 0.65^{b}	3.31 ± 0.27^{b}	55.59 ± 0.65^{f}	20.78 ± 1.43^{a}
	14 (T2)	51.00 ± 0.24^{g}	3.83 ± 0.44^{c}	49.00 ± 0.24^{a}	21.88 ± 1.04^{b}
Lr (P2)	0 (T0)	49.08 ± 0.28^{ef}	2.42 ± 0.13^{a}	50.92 ± 0.28^{bc}	21.38 ± 1.23^{b}
	7 (T1)	41.97 ± 0.81^{a}	2.53 ± 0.22^{bc}	58.03 ± 0.81^{g}	25.98 ± 0.17^{b}
	14 (T2)	48.05 ± 0.67^{de}	3.63 ± 0.35^{bc}	51.95 ± 0.67^{cd}	23.01 ± 1.09^{b}
KF+ Lr (P3)	0 (T0)	50.04 ± 1.13^{fg}	2.38 ± 0.13^{a}	49.96 ± 1.13^{ab}	22.45 ± 1.91^{b}
	7 (T1)	48.41 ± 1.06^{e}	3.48 ± 0.21^{bc}	51.59 ± 1.06^{c}	22.84 ± 0.57^{b}
	14 (T2)	46.95 ± 0.60^{cd}	3.50 ± 0.25^{bc}	53.05 ± 0.60^{de}	22.14 ± 11.07^{b}
P value		0.000	0.017	0.000	0.004
Effect of konjac flour, *L. rhamnosus*, and combination					
Control		44.47 ± 1.44^{a}	3.91 ± 0.80^{b}	55.53 ± 1.44	22.01 ± 1.09^{b}
Kf		48.08 ± 2.93^{c}	3.19 ± 0.66^{a}	51.92 ± 2.93	23.46 ± 2.17^{a}
Lr		46.37 ± 3.37^{b}	3.19 ± 0.62^{a}	53.63 ± 3.37	21.72 ± 1.55^{b}
Kf+Lr		48.47 ± 1.58^{c}	3.12 ± 0.58^{a}	51.53 ± 1.58	22.48 ± 1.17^{ab}
P value		0.000	0.000	0.000	0.030
Effect of storage					
0		48.16 ± 2.21^{b}	2.61 ± 0.37^{a}	51.84 ± 2.21^{a}	22.32 ± 1.45
7		44.41 ± 2.65^{a}	3.50 ± 0.28^{b}	55.59 ± 2.65^{b}	22.81 ± 2.26
14		47.97 ± 2.09^{b}	3.96 ± 0.63^{c}	52.04 ± 2.09^{a}	22.12 ± 0.99
P value		0.000	0.000	0.000	0.377

Note: means in the same column with the different superscript showed a significantly different ($P<0.05$); no addition of konjac flour and *L. rhamnosus* (P0), addition of 0.03% of konjac flour (P1), addition of 5% *L. rhamnosus* (P2), and addition of 0.03% konjac flour and 5% *L. rhamnosus* (P3); storage period of 0 days (T0), 7 days (T1) and 14 days (T2).

Moisture content and total solid

The addition of konjac flour, *L. rhamnosus*, and their combination significantly (P<0.05) affects both moisture content and total solids, as well as the storage duration up to 14 days. The interaction between these factors also shows significant differences (P<0.05). Moisture content is a key to determinant of cheese characteristics as it influences both firmness and softness. In this study, the moisture content was lower compared to the study of Afiati *et al.* (2014), which found soft cheese typically has a moisture content of 55.00-64.01%. According to Wulandari *et al.* (2021), cheese with a moisture content of not more than 80% is classified as soft cheese, thus the cheese in this study is categorized as soft cheese. Moisture content influences the texture of cheese by altering the proteins and fats interaction. Higher moisture weakens the protein network, leading to a softer, more spreadable texture, while lower moisture content creates a firmer texture due to a more compact protein matrix and stronger fat-protein interaction (Lee *et al.*, 2004).

Cheese without the addition of konjac flour and *L. rhamnosus* (P0), as well as cheese with the addition of konjac flour (P1), exhibited increased moisture content after 14 days storage. Conversely, the addition of *L. rhamnosus* (P2) and the combination of konjac flour with *L. rhamnosus* (P3) resulted in reduced moisture content during storage. This finding is consistent with a study of Sumarmono *et al.* (2020), which observed a consistent decrease in moisture content in probiotic soft cheese during storage, affecting the protein, fat, and mineral composition. Setyawardani *et al.* (2019) stated that cold storage could decrease the cheese containing probiotics due to syneresis. In contrast with P0, the increased moisture content is probably due to the addition of acetic acid as a replacement of L. rhanmnosus as acidifier. It is in line with Abd El-Aziz and Abo-Srea (2014) that direct acidification could enhance the moisture content of cheese because of different level of pH compared with using indirect acidification such as LAB culture. The total solids in P2 and P3 increased. Probiotic starter cultures can enhance total solids during cold storage, in line with Setyawardani *et al.* (2019), who noted that the increase in cheese total solids is due to the components constituting the solids and the reduction in moisture content during cold storage.

Ash content

The addition of konjac flour, *L. rhamnosus*, and their combination significantly (P<0.05) increases the ash content, as well as during storage up to 14 days and their interaction. The composition of cheese, including ash content, is influenced by several factors, including differences in processing procedures and raw material used. Changes in composition during cheese storage indicate dehydration, which leads to a reduction in moisture content and an increase in protein, fat, and mineral content (Setyawardani *et al.*, 2019). The ash content in cheese reflects the mineral content present and becomes concentrated in the curd during the coagulation process. The study found ash content ranging from 2.42% to 4.89%, which remains within the standard range. Yulia *et al.* (2015) reported that the ash content of cheese with the addition of *L. casei* at different concentration ranged from 2.64% to 4.00%.

The highest as content was observed in the control group stored for 14 days. Meanwhile, the addition of konjac flour (P1), *L. rhamnosus* (P2), and the combination (P3) resulted in similar ash content levels. During storage, the ash content of the cheese increased. This suggests that *L. rhamnosus* cultures do not utilize many nutrients during storage, thus minerals remain relatively stable. Yulia *et al.* (2015) noted that cheese without added bacteria showed an increase in ash content during storage because the number of naturally occurring LAB in the milk is limited, thereby preserving the minerals. Conversely, mineral loss can occur during whey filtration, as minerals dissolve with the addition of rennet and are removed during the whey filtration process.

Protein content

Cheese with the addition of konjac flour (P1) exhibited a significant decrease in protein content (P<0.05) after 7 days of storage, followed by an increase after 14 days, whereas the protein content in other treatments remained stable (P>0.05) throughout the storage period. This fluctuation is probably due to experimental variability since, to our best knowledge, there was no studies discussing about proteolysis and microbial activity during cheese making and after cheese production. The increase in protein content by day 14 is probably attributed to konjac flour's ability to enhance fermentation capacity, resulting in the production of more acetic acid compared to propionate and butyrate (Harmayani *et al.*, 2014). Konjac flour, rich in glucomannan, acts as prebiotics by serving as a fermentable substrate, promoting the growth and activity of beneficial probiotic microorganisms during fermentation processes (Anggela *et al.*, 2022).

In addition, the protein fluctuation observed can also be attributed to the interactions between konjac flour and protein, primarily due to the gel formation and water retention properties of konjac glucomannan, which affect protein solubility and retention over time (Zhou *et al.*, 2013). These factors likely caused the initial decrease in protein by entrapping or aggregating proteins, followed by stabilization and better retention by day 14, as the konjac matrix matured. Furthermore, the stable protein content during storage is probably due to the inhibitory effect of low temperatures on bacterial and enzymatic metabolism. This finding is in contrast with the study by Setyawardani *et al*. (2017), which reported an increase in cheese protein content during storage due to LAB and protease activity breaking down proteins into simpler peptides and amino acids. The protein in the cheese ranged from 20.13% to 25.90%.

Texture profile analysis

Texture is a critical parameter for determining cheese quality. Generally, texture and acceptability are primary and more significant parameters compared to flavor component in cheese (Aday and Yuceer, 2014). The addition of konjac flour, *L. rhamnosus*, and their combination significantly (P<0.05) affects all texture profile attributes, as well as storage time and their interaction. Seven texture parameters were evaluated: hardness, adhesiveness, resilience, cohesion, springiness, gumminess, and chewiness. The texture profile of cheese with the addition of konjac flour and *L. rhamnosus* during storage is presented in Table 2.

Hardness

Hardness, maximum force required to compress the cheese, increased significantly during storage (P < 0.05), with the highest hardness observed in the control group. The control group exhibited a higher hardness value, whereas the other treatments had lower hardness values. This suggests that the addition of konjac flour and *L. rhamnosus* can soften fresh cheese. These expected findings are probably attributed

Table 2: Effect of konjac flour and *L. rhamnosus* on cheese texture.

Treatments		Hardness	Adhesiveness	Resilence	Cohesion	Springiness	Gumminess	Chewiness
Interaction between konjac flour, *Lactobacillus rhamnosus*, and storage								
Control	0 (T0)	596.87±15.03^{e}	-15.18±6.86^{de}	20.93±1.83^{h}	0.49±0.04^{d}	78.66±1.90^{g}	297.06±30,38^{d}	234.01±28.88^{g}
	7 (T1)	469.84±25.09^{d}	-30.90±6.72^{abc}	19.05±1.33^{gh}	0.51±0.01^{d}	77.94±3.15^{g}	249.15±7,85^{c}	193.90±11.64^{f}
	14 (T2)	647.98±46.22^{e}	-18.21±2.46^{cde}	17.45±1.06^{fg}	0.42±0.02^{c}	66.72±4.67^{f}	281.69±42,68^{cd}	174.29±30.22^{ef}
KF	0 (T0)	243.24±33.40^{a}	-6.31±1.26^{e}	12.34±3.11^{cd}	0.39±0.08^{c}	62.22±4.80^{def}	91.77±25,53^{a}	53.08±27.34^{abc}
	7 (T1)	356.91±22.64^{c}	-26.02±4.23^{bcd}	17.05±0.80^{fg}	0.48±0.03^{d}	64.87±1.38^{f}	162.52±5,35^{b}	115.59±14.13^{d}
	14 (T2)	311.09±37.13^{abc}	-42.07±6.73^{a}	10.22±0.70^{bc}	0.38±0.02^{bc}	47.12±4.39^{c}	117.44±20,52^{a}	55.94±14.08^{abc}
Lr	0 (T0)	327.32±43.52^{bc}	-18.00±2.30^{cde}	16.19±1.07^{ef}	0.51±0.02^{d}	57.53±3.77^{d}	164.37±23,23^{b}	84.56±19.17^{c}
	7 (T1)	474.24±27.62^{d}	-29.72±2.26^{abcd}	19.30±0.90^{gh}	0.54±0.02^{d}	62.84±1.57^{def}	256.62±6,26^{c}	152.58±7.50^{e}
	14 (T2)	337.30±22.42^{c}	-36.42±3.64^{ab}	17.63±0.97^{fg}	0.54±0.03^{d}	63.96±1.07^{ef}	180.74±12,55^{b}	116.61±11.11^{d}
KF+Lr	0 (T0)	318.02±56.90^{abc}	-10.41±2.40^{e}	7.43±0.32^{a}	0.31±0.0^{a}	30.51±2.87^{a}	94.66±19,53^{a}	30.08±8.63^{a}
	7 (T1)	253.22±40.25^{ab}	-41.40±8.19^{a}	13.99±1.30^{de}	0.51±0.02^{d}	59.05±1.58^{de}	125.05±18,40^{a}	74.97±9.51^{bc}
	14 (T2)	383.56±78.62^{c}	27.84±10.40^{abcd}	8.18±1.65^{ab}	0.32±0.05^{ab}	39.93±2.72^{b}	111.61±15,86^{a}	44.08±5.39^{ab}
P value		0.000	0.011	0.000	0.000	0.000	0.000	0.000
Contol		571.56±84.01	-21.43±8.76	19.14±1.96^{d}	0.47±0.05^{c}	74.44±6.52^{d}	275.97±33.92^{c}	200.73±32.14^{d}
KF		303.75±56.61	-24.80±16.02	13.20±3.44^{b}	0.41±0.06^{b}	58.07±8.94^{b}	123.91±35.18^{a}	74.87±34.94^{b}
Lr		379.62±76.45	-28.04±13.15	17.71±1.59^{c}	0.53±0.03^{d}	61.44±3.65^{c}	200.58±44.73^{b}	117.92±31.71^{c}
KF+Lr		318.27±77.10	-26.58±15.08	9.87±3.29^{a}	0.38±0.10^{a}	43.17±12.77^{a}	110.44±20.42^{a}	49.71±21.08^{a}
P value		0.000	0.356	0.000	0.000	0.000	0.000	0.000
Effect of konjac flour, *L. rhamnosus*, and combination (%)								
Contol		571.56±84.01	-21.43±8.76	19.14±1.96^{d}	0.47±0.05^{c}	74.44±6.52^{d}	275.97±33.92^{c}	200.73±32.14^{d}
KF		303.75±56.61	-24.80±16.02	13.20±3.44^{b}	0.41±0.06^{b}	58.07±8.94^{b}	123.91±35.18^{a}	74.87±34.94^{b}
Lr		379.62±76.45	-28.04±13.15	17.71±1.59^{c}	0.53±0.03^{d}	61.44±3.65^{c}	200.58±44.73^{b}	117.92±31.71^{c}
KF+Lr		318.27±77.10	-26.58±15.08	9.87±3.29^{a}	0.38±0.10^{a}	43.17±12.77^{a}	110.44±20.42^{a}	49.71±21.08^{a}
P value		0.000	0.356	0.000	0.000	0.000	0.000	0.000
Effect of storage (days)								
0		371.37±144.32^{a}	-12.48±10.33^{b}	14.22±5.43^{a}	0.42±0.09^{a}	57.23±18.32^{b}	161.96±89.51^{a}	100.43±85.23^{a}
7		388.55±98.56^{ab}	-32.03±7.79^{a}	17.35±2.41^{b}	0.51±0.03^{b}	66.18±7.62^{c}	198.34±59.42^{a}	134.26±46.94^{b}
14		419.98±146.60^{b}	-31.14±10.96^{a}	13.37±4.53^{a}	0.41±0.09^{a}	54.43±12.12^{a}	172.87±74.77^{b}	97.73±56.45^{a}
P value		0.025	0.000	0.000	0.000	0.000	0.000	0.000

Note: means in the same column with the different superscript showed a significantly different (P<0.05); KF: konjac flour, Lr: *Lactobacillus rhamnosus*.

to the ability of *L. rhamnosus* in producing exopolysaccharides (EPS). Kusmiyati *et al.* (2023) observed that *L. rhamnosus* could produce 1059 g/L EPS without the addition of media supplementation. EPS affect protein-protein interactions and act as lubricants or plasticizers between protein in cheese, leading to a decrease in its firmness (Hassan *et al*., 2005). Tomar (2019) also noted that the addition of probiotics and cheese storage affect the texture profile of soft cheese. Storage results in increased hardness of soft cheese. Furthermore, the addition of bacterial cultures also impacts hardness due to bacterial metabolism. With prolonged storage time, cheese hardness increases as moisture content and salt concentration decrease (Guinee, 2004).

Adhesiveness

Adhesiveness is defined as the force required to remove cheese from the probe (Zheng *et al*., 2016). This study results indicate negative values, which are consistent with Tomar's Findings (2019). Nonetheless, the adhesiveness values in this study show a significant decrease in the control and treatment group ($P<0.05$) except the combination of konjac flour and *L. rhamnosus* (P3) which increased significantly ($P<0.05$) over the storage period. Negative adhesiveness values suggest that the cheese has a weaker bond with the probe, possible due to structural changes or a reduction in protein interaction over time. Ouyang *et al.* (2022) reported that konjac flour has the potential to modify texture of cheese matrices, whereas Pires *et al.* (2024) observed that *L. rhamnosus* does not significantly affect the protein structure.

Furthermore, it is more likely that konjac flour helps to reduce the stickiness of cheese. Konjac flour reduces stickiness due to it high amylopectin content (81.8%), which prevents excessive water absorption and maintains a firmer texture (Bo-wen *et al*., 2010). The glucomannan in Konjac flour also absorb water effectively, further reducing cheese tendency to become sticky (Behera and Ray, 2017), leading to a firmer and less adhesive texture of cheese. These findings collectively highlight the dynamic nature of cheese adhesiveness and suggest that both compositional and microbial factors may play a role, although further research is required to elucidate these mechanisms.

Resilience

Resilience refers to the ability of deformed cheese to quickly revert to its original shape once the applied force is removed (Li *et al*., 2024). In this study, resilience was used to assess the texture of cheese supplemented with konjac flour and *L. rhamnosus* during storage. Statistical analysis revealed significant differences ($P<0.05$) in resilience between treatments, indicating that the both supplementation and storage time affect cheese texture. The control group showed a decline in resilience over time, while P2 significantly improved resilience at day 7, with a slight decrease at day 14 of storage. In contrast, P1 showed more fluctuation. The resilience increased at day 7 but decreased significantly at day 14 of storage.

The increase in resilience with *L. rhamnosus* is consistent with studies indicating that probiotics help maintain texture stability in cheese (Karimi *et al*., 2011). On the other hand, konjac flour showed initial improvements but its effect diminished over time, similar to findings by Dai *et al.* (2018) who noted that a decline in texture with prolonged storage due to overhydration and proteolytic changes. The combination of konjac flour and *L. rhamnosus* did not show a clear advantage, suggesting a potential interaction that affects texture stability. Overall, both supplements influence cheese resilience, but storage duration and the specific combination of ingredients play critical roles in maintaining texture.

Cohesion

Cohesion reflects the internal bonding strength of the cheese. In this study, cohesion decreased significantly during storage in the control group ($P<0.05$), whereas it remained stable in the treatment containing *L. rhamnosus* (P2) ($P>0.05$). Notably, the addition of konjac flour, either alone or in combination with *L. rhamnosus*, resulted in increased cohesion values over the storage period. In contrast, Tomar (2019) reported a decrease in cohesion values across all treatments during storage. The differences may be attributed to variations in raw materials or the synergistic effects of konjac flour and *L. rhamnosus* on the protein matrix. Astuti *et al.* (2021) emphasized that raw materials significantly influence the cohesion values of cheese. High cohesion values during storage are preferable as they help maintain the cheese's structure and prevent it from becoming brittle (González *et al*., 2018), thereby contributing to better texture and extended shelf life.

Springiness

Springiness refers to elasticity of cheese after pressure is released, reflecting its ability to return to its original shape (Koranteng *et al*., 2021). In this study, the highest springiness value was observed in the control group (P0), while the lowest occured in treatments containing konjac flour and *L. rhamnosus* (P3). During storage, springiness decreased significantly in the control group (P0) and P1($P<0.05$) after 14 days. Conversely, P2 and P3 exhibited similar springiness after 14 days of storage ($P>0.05$). These results suggest that *L. rhamnosus* may contribute to strengthening the cheese matrix over time, counteracting the structural weakening typically in stored cheese. (Astuti *et al*., 2021) reported that fermentation over 10 days reduced the springiness of cheese made from various milk sources, which partially aligns with the findings for the control group in this study. Moreover, Alqahtani *et al*. (2023), a significant decrease in cheese springiness was noted after one month of storage. However, the observed increase in springiness for treatments containing *L. rhamnosus* may indicate its unique impact on texture, possibly through interactions with proteins or moisture retention. Additionally, maintaining or improving springiness during storge is critical for cheese texture, as it enhances consumer satisfaction and extends the functional quality of the product.

Gumminess

Gumminess refers to the effort required to chew and swallow the cheese, representing its perceived density and cohesiveness. In this study, the control treatment exhibited the highest gumminess values compared to the other treatments during storage. Gumminess increased significantly ($P<0.05$) in the treatments group of P1 and P2, while it decreased significantly ($P<0.05$) in the control group (P0). Notably, gumminess remained stable in the treatments with a combination of konjac flour and *L. rhamnosus* (P3) during storage. These findings suggest that konjac flour and *L. rhamnosus* may interact synergistically to stabilize the texture and structural integrity of the cheese matrix. Astuti *et al*. (2021) reported a decrease in gumminess after 10 days of storage and an increase after 20 days, highlighting the dynamic nature of textural changes during storage. While this study observed both increased and stability depending on treatment, it is likely that the increased gumminess is attributed to water-binding and gel-forming properties, and *L. rhamnosus* may influence protein interaction via fermentation.

Chewiness

Chewiness refers to the energy required to chew the cheese, reflecting its textural density and structural integrity (Papetti and Carelli, 2013). In this study, the control group exhibited the highest chewiness values, indicating that more energy was needed for chewing. However, the chewiness of the control group decreased significantly during storage ($P<0.05$). In contrast, an initial increase in chewiness was observed in all treatment groups after 7 days, followed by further increases noted towards the end of storage period. These findings suggest that storage time and treatment composition play significant roles in shaping the textural properties of cheese.

Parra-Ocampo *et al*. (2020) noted that chewiness is closely related to cohesiveness, with larger curd particle sizes contributing to a stronger cheese structure that requires more energy for chewing. Consistent with these observations, the addition of konjac flour and *L. rhamnosus* resulted in lower chewiness values, potentially due to their effects on the protein matrix and curd formation. Additionally, storage for 14 days reduced the cheese's chewiness across all treatments, highlighting the impact of aging on cheese structure. Astuti *et al*. (2021) reported that while storage influences hardness, springiness, gumminess, and chewiness, it does not affect cohesiveness. The findings of this study align with these observations, further emphasizing the dynamic nature of textural changes.

CONCLUSIONS AND RECOMMENDATIONS

This study demonstrates that the incorporation of konjac flour and *L. rhamnosus*, individually or in combination, significantly enhances the chemical properties and textural stability of synbiotic cheese during storage. The addition of these ingredients reduced moisture content, increased total solids, and enhanced protein content, while also stabilizing ash content due to reduced mineral loss. Texture analysis showed that these treatments softened the cheese, maintained cohesion, and improved springiness and gumminess, contributing to a balanced texture and extended shelf life. Among all treatments, the combination treatment (0.03% konjac flour + 5% *L. rhamnosus*) yielded the most favorable results, maintaining optima quality and mitigating degradation during 14 days of storage.

These findings underscore the synergistic potential of konjac flour and *L. rhamnosus* in developing high quality functional cheese with improved cheese stability over 14 days of storage and textural integrity. By addressing challenges such as moisture loss and texture degradation, this study contributes to advancing the production of sustainable and consumer-friendly dairy products.

Nevertheless, this study was limited to short-term storage and lacked sensory evaluation. Future research should focus on longer storage periods, sensory analysis, probiotic viability, and consumer acceptability to optimize cheese quality. The integration of such innovative approaches could further support the development of functional foods, aligning with the growing demand for health-oriented products globally.

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NOVELTY STATEMENT

The novelty of our study lies in its strong evidence that the incorporation of konjac flour and *L. rhamnosus* in symbiotic cheese formulation enhances both chemical properties and textural stability during storage. For the first time, we demonstrate that their combination optimally maintains moisture retention, improves protein stability, and mitigates texture degradation, leading to a superior functional cheese product with extended shelf life. This study advances the development of high-quality symbiotic cheese, aligning with the increasing consumer demand for functional dairy foods.

AUTHOR'S CONTRIBUTIONS

All authors contributed to the manuscript equally.

Conflict of interest

The authors have declared no conflict of interest.

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