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Application of *Hypsizygus* sp. Chitosan as an Edible Coating to Prolong Shelf Life of Dangke Cheese

Running title: Application of *Hypsizygus* sp. Chitosan to Prolong Shelf Life of Dangke Cheese

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SUMMARY

Research background. Food insecurity is a growing concern, with one-third of food wasted. Mushroom chitosan can be used as a food coating that functions as a barrier, protects food from microbial contamination, and increases shelf life. Although the preservative effects of chitosan have been widely reported, the application of chitosan derived from *Hypsizygus* sp. remains largely unexplored. This study investigates the potential of chitosan from the edible mushroom *Hypsizygus* sp. as a coating on Dangke cheese, a traditional Indonesian cheese made from buffalo milk.

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Experimental approach. Chitosan from *Hypsizygus* sp. was extracted using the alkaline method with NaOH. Chitosan was identified by Fourier Transform Infrared Spectroscopy (FTIR), and then applied as edible coatings on Dangke cheese at mass per volume ratios of 0.1 % and 0.2 %. Chitosan-coated Dangke cheese was then analyzed for its proximate composition, pH, surface morphology, sensory, and microbiological quality compared with uncoated cheese as the control.

Results and conclusions. *Hypsizygus* sp. chitosan has preserved the nutritional value of Dangke cheese while exhibiting minor changes in protein, carbohydrate and fat, also stabilizing pH compared to uncoated cheese. Chitosan at 0.2 % mass per volume ratio reduced spoilage microbes such as *Enterobacteriaceae*, yeast, and mold while allowing beneficial LAB to survive. The morphology and sensory characteristics of chitosan-coated Dangke cheese were considered acceptable.

Novelty and scientific contribution. This study is the first to successfully extract chitosan from *Hypsizygus* sp. mushrooms and to demonstrate that 0.2% mushroom chitosan is highly effective as an edible cheese coating. The study provides evidence that fungal chitosan is a promising option for use in the food industry as a natural food preservative, with potential comparable to commercial chitosan from other sources.

Keywords: *Hypsizygus* sp.; chitosan; edible coating; Dangke cheese; food preservation

INTRODUCTION

A major problem for mankind is food insecurity, driven by the expanding human population. Food security concerns not only the quantity but also the quality of food, including food spoilage that can render food unsafe for consumption. To date, preventing food deterioration while maintaining food quality and ensuring food safety remains a challenge in the food industry. Various studies have been conducted to identify alternative food preservatives derived from natural, biodegradable ingredients that serve as coatings to extend the shelf life and maintain the nutritional quality of foods [*1–3*].

Dairy products, including pasteurized milk, fermented products, and cheese, are susceptible to microbial spoilage during production and storage [*4,5*]. Traditional Indonesian cheese known as "Dangke" features a distinct flavor, compact texture, oval shape, and milky scent. In addition to being cooked, the cheese is occasionally salted, wrapped in banana leaves, and molded in a coconut shell. However, the lack of microbial growth prevention during production and storage limits the product shelf life [*5–7*]. Effective natural preservation is needed to prevent deterioration and extend the shelf life of Dangke cheese while maintaining its physicochemical properties and product quality.

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Chitosan is a biopolymer produced by partial deacetylation of chitin, a major structural polysaccharide found in crustacean shells and fungal cell walls [*8–10*]. In addition to its antimicrobial properties, chitosan is recognized as an edible coating for food preservation, with benefits that include non-toxicity, low allergenicity, and biodegradability [*11*]. A previous study reported the use of commercial chitosan to extend cheese shelf life and inhibit the growth of mold, Staphylococcus, and Enterobacteriaceae [*12*]. Chitosan from champignon mushrooms is also reported to prevent microbiological and physiological degradation of fresh-cut melons, resulting in fewer odor-causing alcohols and more fruity-flavor esters [*13*]. These findings suggest that mushroom-derived chitosan is a promising coating for traditional perishable foods such as Dangke cheese.

Hypsizygus sp. is a nutritious edible mushroom with high demand in both local and international markets, making it popular throughout East Asia, especially in China, Japan, and Korea. It contains essential polysaccharides with anti-inflammatory, antitumor, and antioxidant properties due to the presence of galactose, glucose, mannose, and rhamnose [*14,15*]. *Hypsizygus* sp. was reported to have a considerable amount of chitin (~0.4 % of dry biomass), which can be readily converted into chitosan [*12,16*]. This mushroom could be an economical option for producing natural edible coatings for food preservation due to its extractability, ease of manufacturing, and functional effectiveness [*16*].

This research aimed to study the use of *Hypsizygus* sp.-derived chitosan as a sustainable material for edible coatings in Dangke cheese. To our knowledge, research on the preservation of Dangke cheese, a highly perishable Indonesian cheese prone to microbial contamination, is notably absent. We expected that *Hypsizygus* sp.-derived chitosan coating would improve microbiological quality while maintaining the cheese's physicochemical and sensory properties during storage. This study highlights the unexplored potential of fungal-based biopolymers for improving the shelf life of dairy products and advances the development of natural, biodegradable food technology solutions by investigating their application in traditional cheese preservation.

MATERIALS AND METHODS

Materials

The materials used in this study were fresh *Hypsizygus* sp. mushrooms obtained from the local market in Yogyakarta, Indonesia, Plate Count Agar (PCA), de Man Rogosa Sharpe (MRS), and Violet Red Glucose Agar (VRBGA) media from Oxoid (Basingstoke, UK), and Potato Dextrose Agar (PDA) from HiMedia Laboratories Pvt. Ltd. (Mumbai, India). Sodium hydroxide (NaOH), acetic acid, sodium chloride (NaCl), and other analytical-grade chemicals were purchased from Sigma-Aldrich (St. Louis, MO, USA).

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Preparation of Hypsizygus sp. *chitosan*

Fresh mushrooms were washed with tap water, cut, and oven-dried at 50 °C for 24 h. Dried mushrooms were crushed into a powder, boiled with 2 M NaOH at a 1:20 (*m/V*) ratio, filtered, and washed with double-distilled water and 70 % ethanol until a paste was formed. It was then demineralized by refluxing in 2 % acetic acid followed by centrifugation (4000 rpm, 15 min). To obtain chitosan, the paste was submerged and boiled in 50 % NaOH (1:50 *m*/*V*) for 1 h, then centrifuged at 4000 rpm for 15 min, with distilled water washes in between three times. The pellet was dried in the oven at 55–65 °C for 24 h. The average chitosan yield was expressed as mg/g of dry mushroom mass [*17*].

Fourier Transform Infrared Spectroscopy

The chitosan sample was carefully mixed with KBr at a ratio of (1:5 *m/V*) and then pressed to create a homogenous KBr disk before being exposed to a Spectrum RX I FTIR spectrophotometer (PerkinElmer Inc., Waltham, MA, USA). The infrared spectra of the KBr-supported chitosan were obtained at a resolution of 4 cm^{-1} and in the frequency range of 4000–400 cm^{-1} [*18*].

Preparation and production of edible coating solutions

Dried chitosan (0.1 % and 0.2 %, *m/V*) was dissolved in distilled water containing a mixture of food-grade acetic acid and apple vinegar 1:1 (*V/V*) until a pH of 6.5–7.0. About 2 g of whole cheese samples were immersed in the coating solution for 30 s under airflow in a sterile hood at room temperature and then left for 30 min to ensure complete surface coverage. Uncoated cheese served as the control, and each coated cheese treatment was performed in triplicate [*13*].

Morphological analysis (scanning electron microscope)

Surface morphology of samples was examined using a JSM 6360LA scanning electron microscope (SEM) (Jeol, Tokyo, Japan). Cheese samples were mounted on aluminum stubs and analyzed using secondary electron imaging (SEI) mode. Prior to observation, samples were sputter-coated with a thin layer of gold to improve surface conductivity. Imaging was performed at 10 kV, a working distance of 11 mm, and a spot size of 40. Micrographs were recorded at a magnification of 50× to evaluate the overall surface morphology [*19*]

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Proximate analysis

Proximate analyses were conducted by an accredited laboratory using AOAC method [*20*]. Approximately 2–5 g of the grated cheese sample was used for each analysis. Crude protein content (%) was determined using the Kjeldahl method [*20*]. Fat content (%) was analyzed using a Soxhlet apparatus (Iwaki, Sumedang, Indonesia) with Weibull modification, involving acid hydrolysis followed by extraction using diethyl ether [*20*]. Moisture content (%) was determined gravimetrically by oven drying at 100–105 °C until constant mass, while ash content was measured gravimetrically by incineration at 500–550 °C [*20*]. Carbohydrate content (%) was calculated by difference using the following equation [*21*]:

$$w(\text{carbohydrate})=100-(m_{\text{moisture}}+m_{\text{protein}}+m_{\text{fat}}+m_{\text{ash}}) \quad /1/$$

All proximate analyses were performed in three independent replicates.

Sensory analysis

Sensory evaluation involved 10 untrained panelists from the laboratory personnel and frequent consumers of cheese products. Panelists comprised 3 males and 7 females, aged between 18 and 30 years. Participation was voluntary, and informed consent was obtained from all panelists prior to the evaluation.

Before assessment, cheese samples were equilibrated to room temperature for 1 h and randomly coded to minimize bias. Panelists were seated individually to prevent interaction and reduce potential bias. Water and unsalted crackers were given between samples as palate cleansers. Sensory tests, including odor, taste, texture, appearance, and overall acceptability, were evaluated using a 5-point hedonic scale [*22*]. Ethical committee approval was not required in accordance with institutional guidelines, as the sensory study did not involve any medical interventions or procedures that posed a risk to human health.

pH analysis

A 5 g portion of cheese was homogenized with 45 mL of distilled water at room temperature ((25±2) °C). The suspension was then measured using a calibrated pH meter (Starter 3100-F, Ohaus, New Jersey, USA) in triplicate [*22*].

Microbiological analysis

Various selective media were used to determine the total aerobic plate count (TPC) using Plate Count Agar (PCA), lactic acid bacteria using de Man Rogosa Sharpe (MRS) agar,

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Enterobacteriaceae using Violet Red Bile Glucose Agar (VRBGA), and Yeast and Mold using Potato Dextrose Agar (PDA) media. About 5 g of chopped cheese samples were homogenized with 45 mL of sterile 0.85 % NaCl solution. Serial dilutions were prepared up to 10^{-5} then poured into a Petri dish containing each medium for microbiological analysis. The plates were incubated at 37 °C for 24 h to allow aerobic microbial and Enterobacteriaceae growth, 37 °C for 48 h for lactic acid bacteria growth, and also at 25–30 °C for 3-7 days for yeast and mold growth. Microbiological analyses were performed on days 0, 5, 9, and 11 of storage [*22*].

Statistical analysis

All experiments were done in triplicate. Data were presented as mean±standard deviation (S.D.). Statistical analysis was performed using IBM SPSS Statistics v. 29.0 [*23*]. Microbiological data were analysed using two-way analysis of variance (ANOVA) to evaluate the effects of treatment, storage time, and their interaction, followed by Tukey's HSD post hoc test for multiple comparisons. Proximate composition and pH data were analysed using one-way ANOVA, followed by Tukey's HSD post hoc test for multiple comparisons. A probability value of $p<0.05$ was considered statistically significant.

RESULTS AND DISCUSSION

Identification of Hypsizygus sp*. chitosan*

FTIR analysis was performed to confirm the successful extraction of chitosan from *Hypsizygus* sp., yielding spectra that serve as fingerprints of specific molecular structures and chemical bonds [*24*]. The FTIR spectrum of chitosan extracted from *Hypsizygus* sp. (Fig. 1) exhibited the characteristic absorption pattern of chitosan with unique functional groups, including hydroxyl (-OH) and amine (-NH) groups. These groups contribute to the bioactive characteristics of chitosan, which has a distinctive polysaccharide backbone with hydroxyl and amine groups. In this study, the major absorption bands and their corresponding functional groups are summarized in Table 1. Chitosan's hydrophilic character, which influences its solubility in acidic solutions, is evidenced by the strong absorption bands at 3448.72 and 3271.27 cm^{-1}. The protonation of amine groups at low pH improves the substance's water dispersibility [*25*].

The functional groups in chitosan from *Hypsizygus* sp. may enhance its antibacterial and antioxidant properties, making it a viable natural preservative for food. The amine ($-NH_2$) and hydroxyl (OH) groups enhance chitosan's ability to form protective coatings through hydrogen bonding with

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food matrices. In acidic conditions, the positively charged amine groups disrupt microbial cell membranes, leading to bacterial cell death and extended shelf life for food products [*26*].

The alkaline extraction yielded about 11.5 % chitosan based on the dry mass of *Hypsizygus* sp. (data not shown). In general, a higher yield suggests effective deacetylation of chitin and preservation of the polysaccharide backbone [*25*]. The achieved yield is comparable to previous studies that obtained chitosan from different species, such as *Lentinula edodes*, a mushroom in the same order as *Hypsizygus* sp. [*27*]. The yield may be affected by variations in the chitin content of fungal biomass, reaction time, and deacetylation temperature. These factors impact the solubility and structural integrity of the final chitosan product.

Physicochemical analysis of Dangke cheese

Proximate analysis of uncoated and chitosan-coated cheese

Proximate analysis of uncoated and chitosan-coated Dangke cheese at different mass per volume ratios is shown in Table 2. In this study, the moisture content varied among treatments, with the 0.1 % chitosan-coated sample showing a higher moisture content (49.82 %) compared to the 0.2 % chitosan-coated cheese (47.71 %). However, both coating treatments in Dangke cheese showed no significant difference in moisture compared with the uncoated control cheese (48.09 %), indicating that coatings did not cause moisture loss during Dangke cheese storage. This was in contrast to a previous study that showed edible coatings could influence moisture migration in food systems [*28*].

At 0.1 % chitosan-coated cheese, the ash content was found to be slightly reduced (2.91 %) compared to 0.2 % chitosan-coated cheese (3.01 %) and control (3.05 %) (Table 2). Even so, there was no significant difference between 0.2 % chitosan-coated cheese and the control, indicating that chitosan coating had little effect on the ash content of Dangke cheese. A statistical comparison of protein, carbohydrate, and fat in both coating treatments revealed no significant differences from the control, suggesting that the chitosan coating did not substantially alter the proximate composition of dairy products as previously reported by El-Sayed *et al.* [*29*]. These findings suggested that chitosan can be used as a preservative without adversely affecting the nutritional composition of Dangke cheese.

pH value of uncoated and chitosan-coated Dangke cheese

During 11 days of storage, the pH of Dangke cheese decreased slightly across all treatments, including control (Fig. 2). This slight pH drop may be due to microbial activity, specifically from organic acid-producing lactic acid bacteria. This phenomenon indicates that storage time was a major factor

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affecting cheese acidity. Moreover, the pattern illustrates the partial impact of chitosan on pH changes during storage, as chitosan can dissolve in acidic solutions, thereby lowering pH. These results were in accordance with a previous study from Di Pierro *et al.* that showed pH reduction of both chitosan-coated and uncoated Ricotta cheese during storage due to the lactic acid bacteria activity, proteolysis, and lipolysis [*12*].

Morphology and sensory characteristics of uncoated and chitosan-coated cheese

Microscopic observation revealed differences in the external surface morphology between uncoated cheese (Fig. 3a) and 0.2 % chitosan-coated cheese (Fig. 3b). The external surface of chitosan-coated cheese exhibited an uneven shape, identifiable clusters, and a more porous and irregular structure. This suggests that the cheese's rough texture is a result of the protective layer the chitosan coating has formed on it. The natural structural characteristics of the chitosan film, which may facilitate gas exchange while maintaining its barrier function, could be responsible for the porous appearance.

The sensory evaluation of cheese samples treated with different chitosan concentrations revealed differences in panelists' acceptance of flavor, odor, texture, appearance, and overall acceptability. The most adverse effect was on flavor (Fig. 4a), with both coated cheese treatments receiving higher dislike scores than the control. Most panelists had the same preference for the odor of 0.2 % chitosan-coated cheese as that of the control (Fig. 4b). All samples received similar scores for texture and appearance (Fig. 4c and Fig. 4d), which is in accordance with previous research [*12,29*]. Overall, chitosan coatings are considered acceptable (Fig. 4e), but their flavor impact must be addressed to increase customers' preference.

Microbiological analysis of uncoated and chitosan-coated Dangke cheese

The results of microbiological analysis of Dangke cheese products preserved with *Hypsizygus* sp. chitosan and the control during 11 days of storage are shown in Fig. 5. The effects of chitosan treatment, storage time, and their interaction were evaluated using two-way analysis of variance (ANOVA), followed by Tukey's HSD test for post hoc comparisons at $p<0.05$. The results showed differences in overall aerobic plate counts across treatments and storage periods (Fig. 5a). Compared with the control and low-chitosan treatments, the high-chitosan treatment displayed significantly lower numbers at day 0. By day 5, there were no noticeable differences between the treatments. At days 9 and 11, the three treatments differed significantly, with the high-chitosan treatment showing the lowest counts. This suggests potent antibacterial activity, as chitosan can bind to microbial DNA, disrupt cell

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membranes, and chelate nutrients required for bacterial growth [*30*]. The group treated with a lower mass per volume ratio of chitosan showed considerable stability, while also suggesting that higher ratio of chitosan can be used as a natural preservative to increase the microbiological shelf life of fresh cheeses like Dangke.

Enterobacteriaceae were detected on day 0 in both coated and uncoated Dangke cheese, at approximately 8 log CFU/mL, a relatively high level for fresh cheese, which may indicate poor hygiene during Dangke processing or contamination during coating due to the high nutrients in milk as raw materials for cheese making [*31,32*]. These findings were consistent with Mladenović *et al.*, who reported that raw milk cheese contained the highest number of Enterobacteriaceae during the first days of ripening [*33*]. A previous study by Hassan *et al.* reported high levels of *Enterobacteriaceae* (approximately (6.64±0.42) to (7.42±0.31) log CFU/mL) in Kareish cheese on day 0 of observation [*34*]. As shown in Fig. 5b, no significant differences among treatments were observed on days 0 and 5. In contrast, on days 9 and 11, the control exhibited significantly higher Enterobacteriaceae counts than both chitosan treatments. This also corresponds to a previous study in which chitosan-gelatin-based coating on Kareish cheese could decrease Enterobacteriaceae up to the 15th day of storage [*34*]. Chitosan's antibacterial activity likely suppresses *Enterobacteriaceae* by disrupting bacterial cell envelopes. The polycationic properties of chitosan inhibit bacterial growth and nutrient uptake in Gram-negative bacteria, consistent with previous research indicating that chitosan reduces the abundance of Gram-negative bacteria without compromising the cheese's nutritional value, especially at higher concentrations [*28,35*]. The present results support these mechanisms and suggest the antibacterial effect of *Hypsizygus* sp. chitosan was maintained during Dangke cheese storage. However, the very high initial Enterobacteriaceae counts in both coated and uncoated Dangke cheese should be highlighted as a study limitation, as they indicate considerable pre-existing contamination prior to coating application.

From our study, lactic acid bacteria increased after day 5, particularly in the low chitosan treatment. This trend was quantitatively evident from increasing log CFU/mL values, suggesting that LAB became the dominant microbial group during later storage phases (Fig. 5c). Statistical analysis indicated no significant differences among treatments on day 0. However, on days 5, 9, and 11, the low-chitosan treatment resulted in significantly higher LAB counts compared to both the control and high-chitosan treatments. This observation aligns with previous studies indicating that LAB exhibit greater tolerance to chitosan, particularly under acidic conditions [*36*]. This selective effect represents

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a beneficial outcome, as LAB dominance may contribute positively to flavor development and microbiological stability in fresh cheeses.

Lactic acid bacteria (LAB) play a crucial role in cheese fermentation and flavor development. The acidic pH in coated cheese makes the environment more suitable for LAB growth. Moreover, this could be due to the characteristic of LAB as Gram-positive bacteria that show less sensitivity to chitosan, especially at higher concentrations. LAB's thicker peptidoglycan layer may serve as a barrier to limit contact between the bacterial membrane and the positively charged amino groups in chitosan. This observation was in accordance with previous studies indicating that LAB exhibit greater tolerance to chitosan, particularly under acidic conditions [*36*]. Therefore, the use of chitosan coating can indirectly support the growth of LAB while contributing to changes and stability of the microbiological quality of Dangke cheese.

Microbiological analyses showed that *Hypsizygus* sp. chitosan at both low and high mass per volume ratio could inhibit yeast and mold growth, although its contribution to the observed reduction requires further investigation (Fig. 5d)**.** By days 9 and 11, no yeast or mold colonies were detected in any treatment, including the uncoated cheese control, indicating that fungal counts were below the detection limit. This suggests that fungal proliferation remained below the detection limit during the later storage period, consistent with the reported antifungal potential of chitosan in UF soft cheese [*29*]. However, the observed reduction cannot be solely associated with chitosan, as neither yeast nor mold colonies were observed in the uncoated control. This result could have been influenced by other factors such as pH, storage temperature, and the initial fungal population. Therefore, further studies with improved control of initial fungal contamination and a clearly defined detection limit are needed to determine the antifungal efficacy of the coating.

CONCLUSIONS

The study results showed that FTIR confirmed the successful extraction of chitosan from *Hypsizygus* sp. The application of *Hypsizygus* sp. chitosan as a preservative effectively coated the surface of Dangke cheese while maintaining acceptable sensory properties. The pH of chitosan-coated Dangke cheese decreased slightly, while its proximate composition remained relatively unchanged during storage. In addition, Dangke cheese coated with 0.2 % *Hypsizygus* sp. chitosan demonstrated effective protection against spoilage microorganisms while maintaining beneficial bacteria. Future studies should evaluate the optimization of chitosan extraction and also investigate its preservative mechanisms under commercial storage conditions.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ETHICS APPROVAL

Ethical approval was not required under institutional guidelines for this study. Sensory evaluation was conducted with voluntary participants who provided informed consent prior to participation

AUTHORS' CONTRIBUTION

Z. F. Annisa contributed to the conception or design of the work, data collection, data analysis and interpretation, performing the analysis, and drafting the article. W. Raksamat contributed to the critical revision of the manuscript. S. Darmasiwi contributed to the conception of the work, drafting, and critical revision. All authors approved the final version of the manuscript.

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Table 1. Comparison of chitosan peaks in *Hypsizygus* sp. mushroom

Molecules	$\tilde{v}$/cm^{-1}		
	Chitosan based on literature	Chitosan obtained from *Hypsizygus* sp. mushroom	Functional group range
Group tension -OH	3450	3448.72	3650-3400
Group tension N-H	3292	3271.27	3292
Group tension C-H	2919 and 2868	2924.04 and 2854.65	2919 and 2868
Tension CH3	1430	1442.75	1430
Doubling the Group -NH2	1550	1558.48	1560-1500
Amide III	1385.6	1388.75	1390-1370
Carbon dioxide O=C=O	2352.2	2345.44	2349
Amide I	1647.4	1558.48	1650 1550
Amide IV	596	740.67	800-600

Table 2. Proximate analysis of uncoated and coated Dangke cheese at different mass per volume ratios of *Hypsizygus* sp. chitosan during 11 days of storage

(*m*(chitosan)/*V*(solution))/%	w/%				
	Moisture	Protein	Ash	Carbohydrate	Fat
0 (control)	(48.09±0.45)^{ab}	(13.79±0.25)^{a}	(3.05±0.01)^{b}	(7.08±0.45)^{a}	(28±0.24)^{a}
0.1	(49.82±0.57)^{b}	(13.83±0.13)^{a}	(2.91±0.01)^{a}	(5.96±0.57)^{a}	(27.50±0.15)^{a}
0.2	(47.71±0.08)^{a}	(14.46±0.13)^{a}	(3.01±0.04)^{ab}	(5.51±1.48)^{a}	(28.81±0.69)^{a}

Data are presented as mean±standard deviation (S.D.) from triplicate analyses. Different superscript letters within the same column imply significant differences ($p<0.05$) according to Tukey's HSD test

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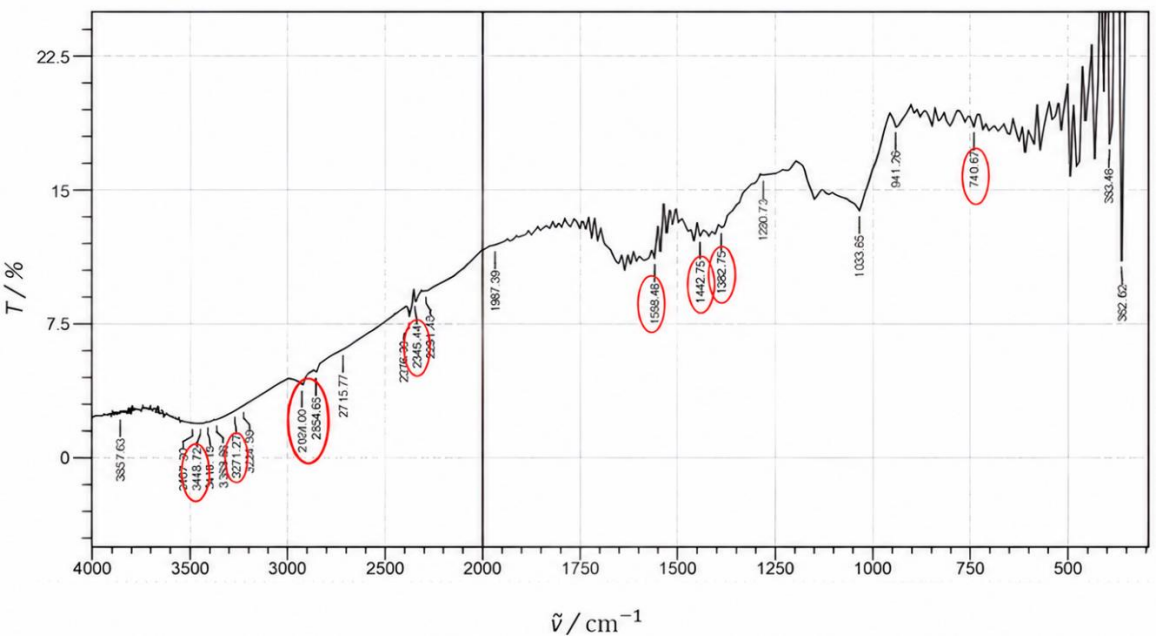


Fig. 1. Peaks of chitosan from *Hypsizygus* sp. extraction

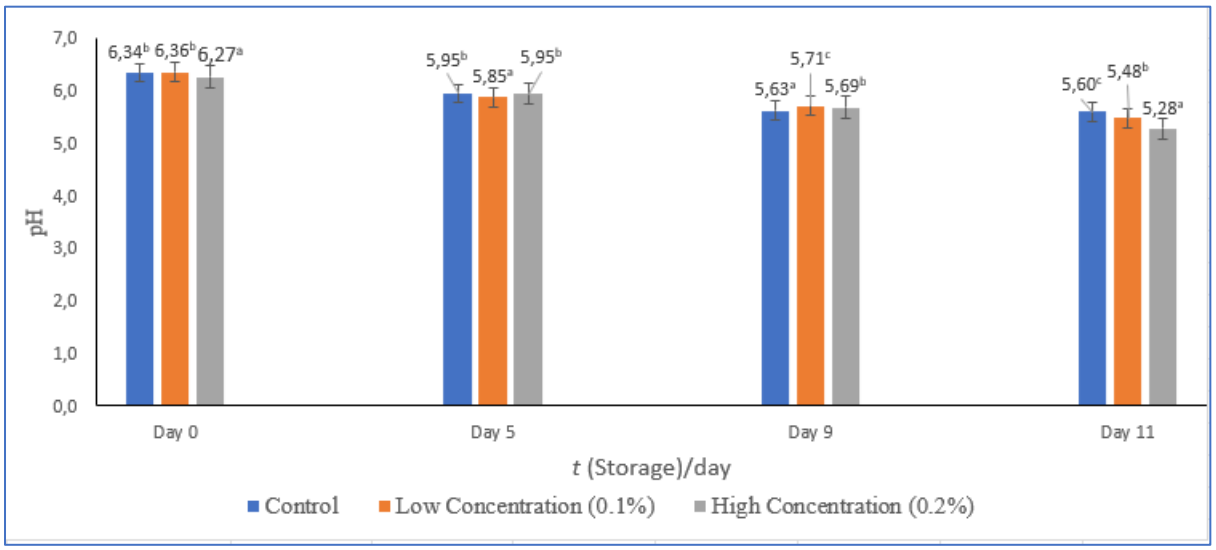
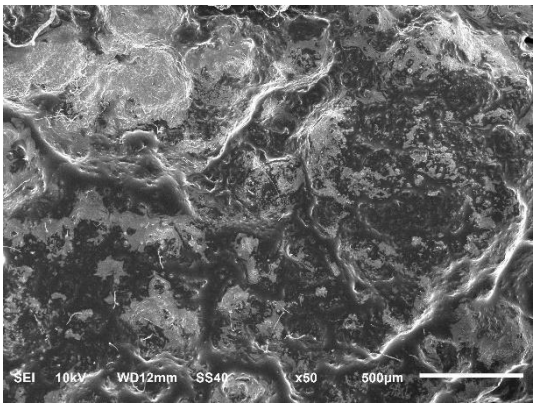


Fig. 2. Changes in pH of uncoated and chitosan-coated Dangke cheese during 11 days of storage. Different superscript letters indicate significant differences among treatments at the same storage time ($p<0.05$) according to Tukey's HSD test

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a)



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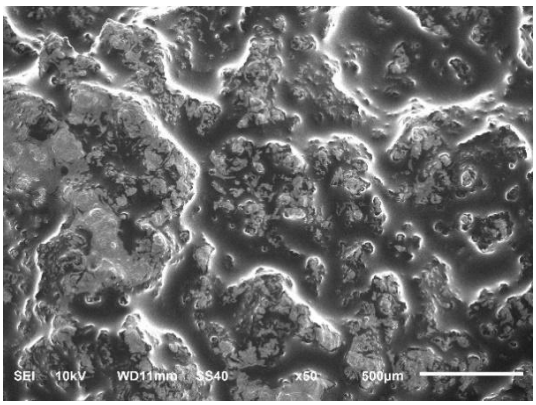
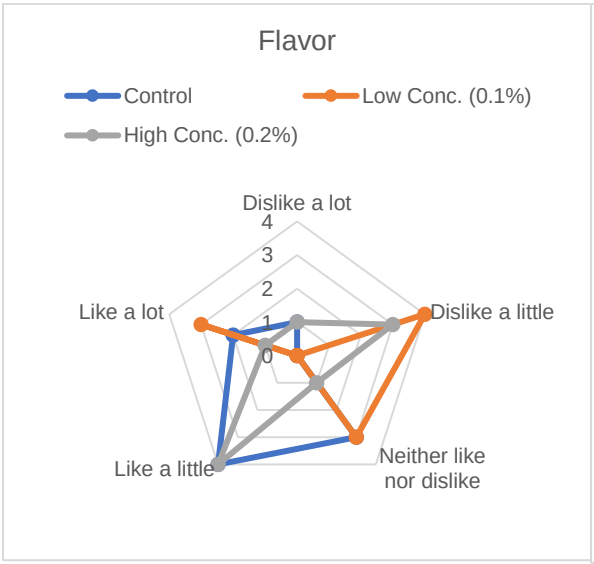
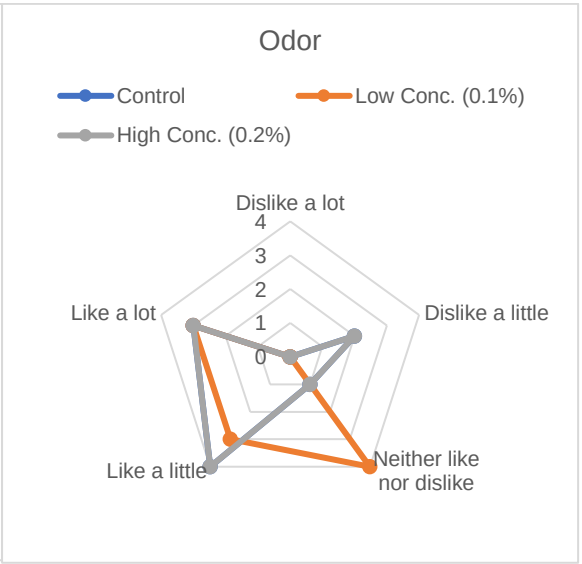


Fig. 3. Scanning electron microscopy (SEM) micrographs (50× magnification) of the external surface of Dangke cheese: a) uncoated cheese and b) 0.2% chitosan-coated cheese

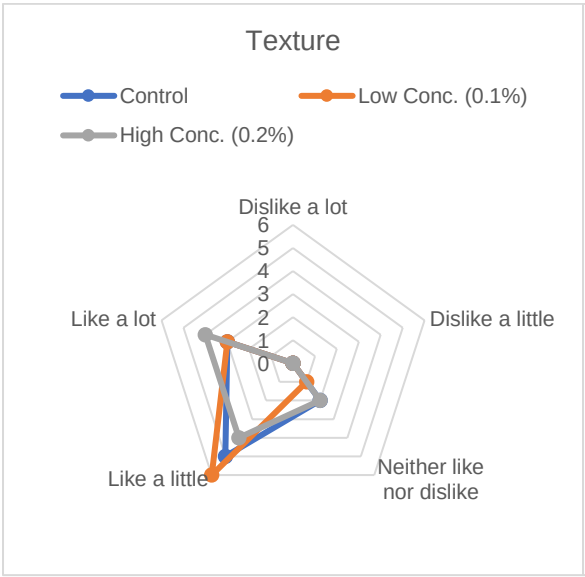
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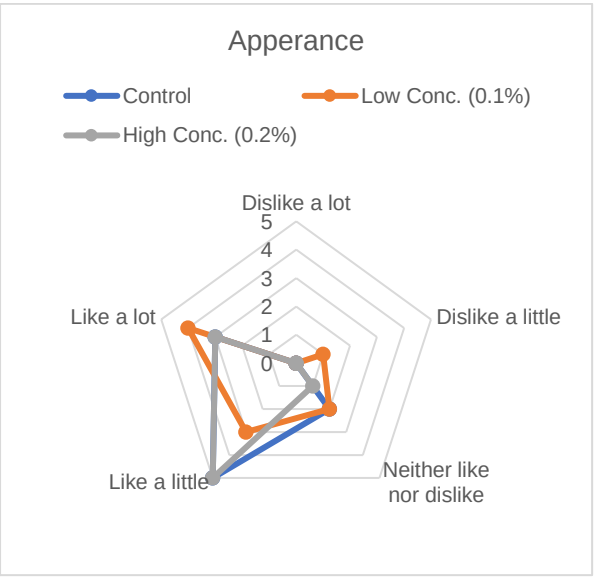
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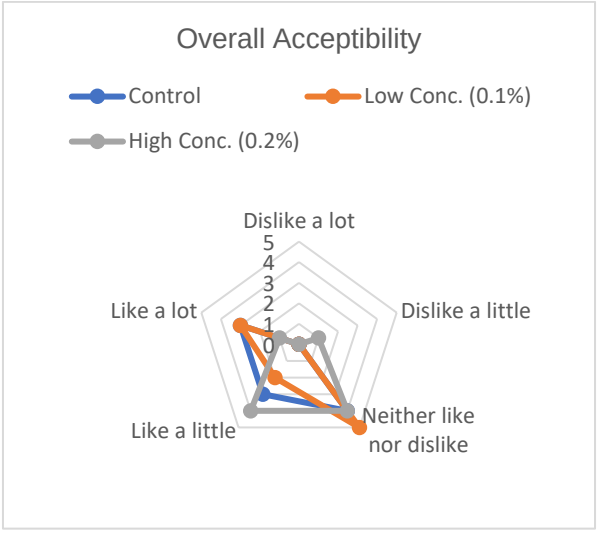


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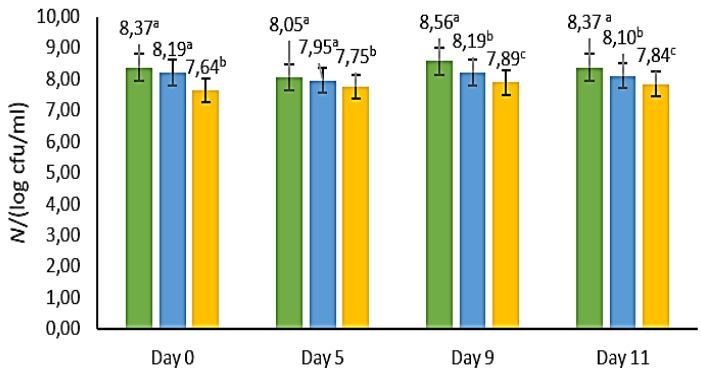
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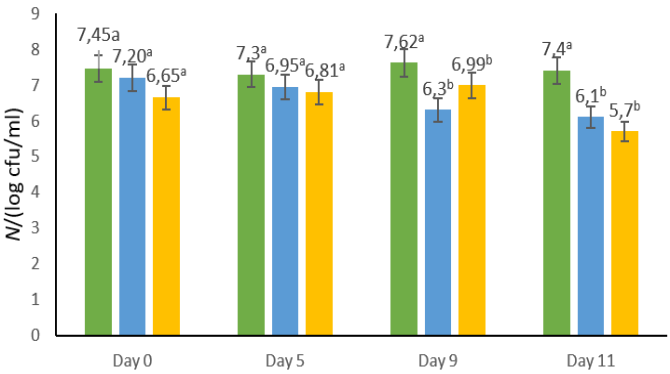
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Fig. 4. Sensory evaluation of uncoated and chitosan-coated Dangke cheese for a) flavour, b) odor, c) texture, d) appearance, and e) overall acceptability

a)

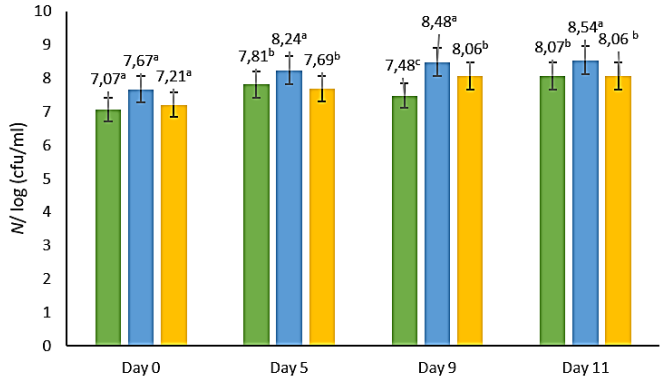


b)



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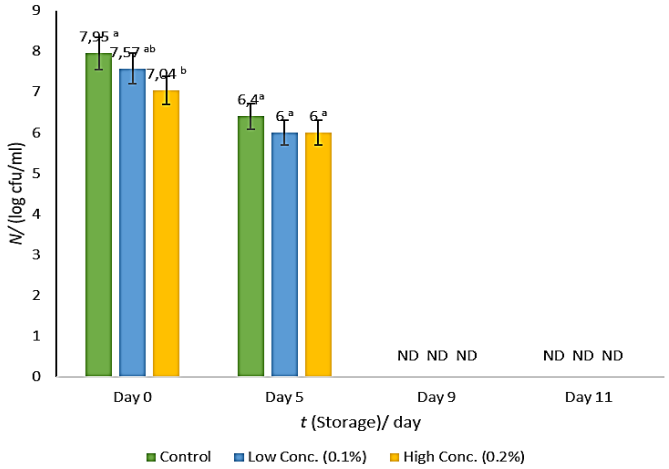


Fig. 5. Effect of chitosan as an antimicrobial on: a) total plate count, b) Enterobacteriaceae, c) lactic acid bacteria, d) yeast and mold. ND=not detected. Different superscript letters within the same storage time indicate significant differences among treatments ($p<0.05$) based on Tukey's HSD test