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Edible Coating Application Based on Snail Shell Chitosan in the Effort to maintain the Quality and Storage of Tofu

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Abstract: Tofu also has a weakness, namely its high water content, so it is easily damaged because it is easily overgrown by microbes. Preservatives added are not limited to preservatives that are allowed, but many businessmen are naughty by adding formalin. White tofu is one that is circulating in the market. At room temperature the yower storage knows an average of 1-2 days. Efforts to preserve tofu by means of steaming and storing in a refrigerator can only preserve tofu for 1 day. This causes traders to commit fraud, one of which is preserving tofu so that it is durable, one of which is the addition of chemicals. According to the Food and Drug Supervisory Agency (BPOM). The treatment research method with the application of chitosan as an edible coating on white tofu is carried out in four stages, namely the preparation stage, immersion stage, storage stage, and testing stage. The preparation stage is carried out by preparing all the materials and tools that will be used in the immersion, storage and testing stages. The immersion stage was done by soaking white tofu with concentrations varying of 0.5% The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition 0.01 %.

Keywords: Chitosan; Chitin; Edible, Organoleptic Test, Tofu

Introduction

Food is one of the basic and primary necessities of human life besides clothing and shelters. Food plays an important role in human life to survive. Therefore, a guarantee is needed that the food consumed daily by humans has a high level of safety, so that humans can avoid disease or dangers originating from food. According to the Government Regulation of the Republic of Indonesia number 28 of 2004, food shall be everything originating in biological resources and water whether processed or not, designed as food or beverage for human consumption, including food additive, food raw material and other materials used in the preparation, processing and/or production of food or beverage (Pérez-Marroquín et al., 2023); (Rațu et al., 2023). One of the food safety issues which still requires supervision is the use of Food Additives for various purposes. Food Additives are also commonly referred to food chemicals or food additives (Paramasivam et al., 2024); (Recoules et al., 2025). In order to prevent microbial growth that causes spoilage, some producers use synthetic preservatives and antioxidants such as formalin, benzoic acid, BHA (Butylated Hydroxyanisol), BHT (Butylated Hidroxytoluene) and TBHQ (Tertier Butylated Hydroxyanisole), especially for semi-moist food compositions such as tofu, noodles, meatballs, fish, meat and oil/fat, etc. which are sourced from petroleum or synthetic materials (Saget et al., 2021); (Andreani et al., 2023).

Health department currently does not recommend the use of preservatives and synthetic antioxidants because they are potentially harmful additives and are associated with an increased risk of cancer (*Carcinogenic*

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Agent). Tofu is one type of traditional food that is widely consumed by the community and often contains formaldehyde. Based on the result of study conducted by Hasrudin on 2020, it showed that out of 17 tofu samples, there were 10 samples which were traded at the City Central Market and Wua-Wua Central Market containing formalin. The highest level of formaldehyde was found at the City Central Market 4, namely 81.1 mg/g, while the lowest was found at the City Central Market 11, namely 47 mg/g. Tofu is a popular food among Indonesians even though it originates from China. Tofu becomes a popular side dish in Indonesia because it not only tastes good, but also is cheap and easy to make. It is also can be processed into various forms of foods and beverages. Tofu manufacturers in Kalisari Village, Cilongok District, produce two types of tofu, namely yellow tofu and fried tofu. The selling size and price of tofu produced varies per piece according to the buyers' tastes.

The selling price of small tofu is Rp. 100.00 per piece, some are priced at Rp. 200.00, Rp. 300.00, and the largest ones are sold for Rp. 500.00 per piece. In addition, tofu is categorized as a health and nutritious food because it is high in protein and its quality is equivalent to animal protein (Hammer et al., 2024); (Sheffield et al., 2024). This can be seen from the NPU (Net Protein Utilization) value of tofu which reflects the amount of protein that the body can utilize, which is around 65%, besides having a high digestibility of around 85-98%. Unfortunately, high water content in tofu makes it easily because it is easily grown by microbes. In order to extend tofu's shelf life, most tofu producers in Indonesia add preservatives. Nowadays, sadly many tofu producers have taken manipulative actions to anticipate any losses by adding preservative such as formalin (Rathee et al., 2023); (Mafe et al., 2024). Whereas Regulation of Minister of Health Number 33 of 2012 prohibits formalin from being used as a food additive. This happens due to a lack of producer knowledge regarding food safety, especially in the manufacturing (Rahman et al., 2023).

White tofu is a type of tofu produced and sold in the market. At room temperature, tofu has a shelf life of only a 1-2 day. Tofu can have longer shelf life if it is preserved by steaming or stored in a refrigerator for 1 day (Dżugan et al., 2024); (Kobayashi et al., 2020). This weakness causes traders to commit fraud, one of which is preserving tofu by adding chemicals ingredient. According to the Food and Drug Supervisory Agency (BPOM), currently a lot of formalin is misused as a preservative in food products such as tofu. Formalin is used more by traders and tofu producers for the preservation process because formalin is easier to obtain and the price is relatively cheap (Prima Arumsari et al., 2017); (Nabila et al., 2019). Food technological advances have resulted new discoveries especially as a substitute for formaldehyde with the use of preservatives from natural ingredients (Dey and Nagababu, 2022); (Rathee et al., 2023). One example of a natural preservative which has a strong anti-microbial effect and can be used in food because it is non-toxic and safe for the human body is chitosan (Thaivalappil et al., 2025); (Punia Bangar et al., 2021); (Dai et al., 2022). The use of chitosan from shrimp shells as a natural preservative can maintain the shelf life of tofu products for 13 days with the ideal storage temperature of 4 °C for both methods of treatment of chitosan preservatives. Further, making chitosan from snail shells *(Achatina Fullica*) is very potential because snail breeders and food stalls serving snails in Indonesia are very abundant. This snail shells waste can be obtained from food stalls that serve snails dish (Nkansah et al., 2021)

Based on the description of the problem above, researchers try to utilize snail shells as an alternative to natural preservatives for tofu, by using the Edible Coating method. By investigating benefits of snail shells, the researchers can show the value of snail shells which so far have only been considered waste by the community.

Method

Snail shell preparation includes washing, drying, crushing with a blender and sifting. Washing was carried out to clean the shells from dirt. Then to reduce the size of the snail shells, the researchers used a pestle and mortar. Then the researchers sifted the snail shell flakes by using a 200-mesh sieve.

Chitosan isolation

Chitosan isolation includes several processes, namely deproteination, demineralization, and deacetylation processes. Chitin purification was carried out using the Hong method in the following way

Deproteination

The researchers put 100 g of snail shell powder in a 1000 ml beaker and added to a 3.5% NaOH solution with a ratio of 10:1 (v/w), then it was heated while stirring with a magnetic stirrer for 2 hours at a temperature of 65 ^{o}C. Once it was cool, it was filtered and neutralized with distilled water. The solid obtained was dried in an oven at 60°C until it was dry.

Demineralization

Deproteinated snail shell powder was added to HCl 1 N solution with a ratio of 15:1 (v/h) in a 1000 ml beaker glass and heated at 40 °C while stirring with a magnetic stirrer for 1 hour, then it was cooled. Filtered and neutralized with distilled water, then it was dried in an oven at 60°C.

Deacetylation

On deacetylation process, the researchers added 60% NaOH with a ratio of 20:1 (v/w) and it was heated at 100°C for 1 hour. After chilling, it is filtered and the solids obtained are neutralized with distilled water. The result was mixed in a 2% acetic acid solution so that the impurity material was wasted. The solids were then dried in an oven at 80°C and the chitosan was ready to be analyzed using FTIR instruments.

Proses edible coating

The application of chitosan as an edible coating on white tofu is carried out through four stages, namely the preparation stage, the soaking stage, the storage stage, and the testing stage. The preparation stage was carried out by preparing all the materials and tools that will be used in the immersion stage, the storage stage and the testing stage. The soaking stage was carried out by soaking white tofu with varying concentrations, namely 0.005%, 0.01% and 0.015%. After that, the tofu storage stage was carried out at room temperature until there was a physical change in tofu, between observations on day 0, day 1, and day 5 (to test the effect of concentration on storage time). Furthermore, organoleptic testing of tofu was carried out by soaking tofu at one of the best concentrations, then it was stored for 24 hours. Then an organoleptic test was carried out which consisted of texture, aroma, color and firmness of the tofu samples.

Results and Discussion

FTIR analysis of chitosan from snail shells

The transformation of chitin into chitosan is called a hydrolysis reaction. This reaction mechanism begins with the entry of the hydroxyl group (OH^-) from NaOH to the C carbonyl atom. This occurs because the hydroxyl group has a lone pair which is nucleophilic. The entry of the hydroxyl group occurs at the C carbonyl atom due to an induction effect so that the electrons on the C carbonyl atom lead to the O atom. As a result, the C carbonyl atom becomes very electropositive. The process causes the π bond to break at the C=O carbonyl. The O atom on the hydroxyl (OH^-) is able to attract electrons on H, causing the formation of a proton. N atoms which have one pair of free electrons can attract protons to form ammonium ion. To stabilize the N atom, the N-C bond is broken, accompanied by the formation of a C=O bond to form chitosan (Wahyuni, et al., 2016). The results of the FTIR analysis of snail shell chitosan can be seen in Figure 1 below:

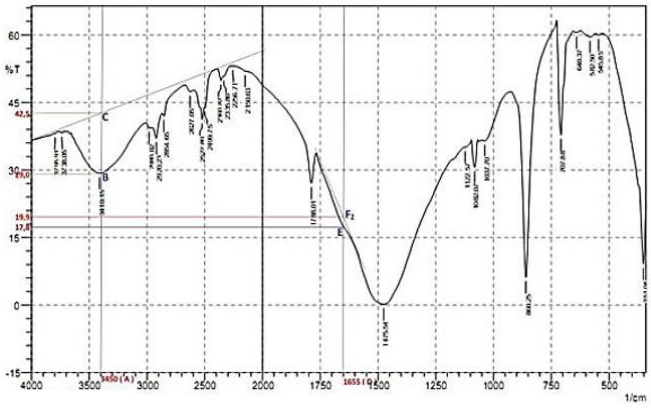

Figure 1. FTIR analysis results of snail shell chitosan

The result of deacetylation process was in the form of a yellowish-white dry precipitate of 32.5502 g or about 65.0853% of chitosan powder with a degree of deacetylation of 78.0616%. The diacetylation process aims to remove the acetyl group from chitin so that it becomes chitosan, in other words chitosan is chitin which loses the acetyl group. During the process there is a change on the acetyl group ($-HCOCH_3$) to an amine group ($-NH_2$). The deacetyl reaction is basically an amide hydrolysis reaction of β–(1-4)-2-acetamide-deoxy-D-glucose with NaOH.

Test results of tofu storage time

The test results for the length of storage of tofu coated with chitosan with several concentration variations, namely 0.005%, 0.01961% and 0.015% can be seen in Table 1 below.

Table 1. Tofu storage time test

Chitosan concentration (%)	Days to	Observation Results		
		B«	Textur	Color
0	2	+-	+-	+-
	3			
	4			
	5			
0.005	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			
0.01	2	+	+	+
	3	+	+	+
	4	+	+	+-
0.015	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			

Information:
+ : Fresh tofu does not smell bad, has good texture, not moldy, white color.
+- : slime appears, bad smell, dingy white color. Slimy tofu, moldy, foul smelling and brownish yellow

The results of the storage time test shown in Table 1 showed that tofu soaked in chitosan solution with the addition of 0.01% was able to keep its freshness until the 4th day. This was much better than tofu without chitosan coating which only survived on the 2nd day, whereas tofu soaked in chitosan solution with the addition of 0.005% and 0.015% only kept its freshness until the 3rd day. On the fifth day, all the tofu was slimy, smelled bad, moldy and the texture started to crumble along with a change in color to brownish. The presence of mucus and this foul smell indicates that the tofu has been damaged. Mucus formation is caused by the hydrolysis of starch and protein by *Bacillus, Clostridium* and *Coliform* bacteria and produce a sticky material. Tofu with a concentration of 0.01% chitosan solution was able to survive until the 4th day. The color of tofu on the 4th day becomes dull white but it did not smell and was slimy. In tofu coated with chitosan with the addition of 0.01% chitosan concentration, it showed that the tofu remained fresh until the 4th day. explained that the mechanism which occurs in food preservation by chitosan is that chitosan molecules have the ability to interact with compounds on the surface of bacterial cells and then are adsorbed to form layers that inhibit cell transport channels so that cells experience a lack of substance to develop and result in cell death (Smułek and Kaczorek, 2022); (Lobiuc et al., 2023); (Guzmán-Soto et al., 2021).

On the 5th day, all the tofu had been damaged, including tofu at a concentration of 0.01%, this happened because the tofu edible coating used had been saturated so that it could no longer be adsorbed to form a layer that could inhibit the growth of bacteria in the tofu samples. This is in accordance with research conducted by (Al-Maqtari et al., 2023); (Geng et al., 2024); (Chen et al., 2022), which said that chitosan solution was able to maintain the freshness of tofu for more than 4 days with a concentration of 4 gr/L. Meanwhile, research conducted said that the application of chitosan with the coagulant method produced tofu products that could last 14 days in good condition, while tofu products using the edible coating method produced tofu products that could last 13 days. at 4 ^{o}C storage temperature. Chitosan has hydrophilic groups, namely primary and secondary hydroxyl groups at C^{-3} and C^{-6} which causes chitosan to have high chemical reactivity, so that chitosan has the ability to bind water making it difficult for bacteria to develop (Yadav et al., 2024); (Román-Doval et al., 2023).

Organoleptic test

Organoleptic testing involves the assessment of color, texture, odor, mucus and fungi of a food product, in this case was tofu. Testing was carried out at the beginning of storage day 0 until storage day 3. The findings of organoleptic test of tofu can be seen in Table 2 below.

Table 2. Tofu Organoleptic Test

		Observation Results		
Chitosan concentration	Day to	Aroma	Texture	Color
0	3	Rotten	Crushed and Watery	Brown
0.50	3	Rotten	Soft and Watery	Gloomy White
1	3	Good	Chewy and Good	Pure White
1.50	3	Smelly	Chewy and Watery	Yellow

Color

The organoleptic test results showed that the soaking treatment had a significant effect on the color of the tofu on the 3rd day of storage. The test results showed that there was a significant difference between the control treatment and chitosan at concentrations of 0.05%, 0.01% and 0.015%. This can be seen from the organoleptic value of the tofu color given the chitosan treatment of 0.05%, 0.01% and 0.015% which has a better record compared to the control tofu. Changes in color will indicate changes in nutritional value, so that changes in color are used as an indicator of the level of maximum nutritional value received (Razzak et al., 2023).

Aroma

The organoleptic test results showed that there was a difference between the control treatment and chitosan at concentrations of 0.005%, 0.01% and 0.015%. This can be seen from the organoleptic value of tofu aroma given 0.01% chitosan treatment which has a better response compared to the control tofu. One of the aroma indicators is spoilage which can affect the acceptance and rejection of food products (Shaik et al., 2022); (Karnwal et al., 2025); (Fletcher et al., 2018); (Thamsborg et al., 2023). The aroma of a food determines the delicious taste of the food itself because with the sense of smell, humans know whether a food is delicious or not, which they have not seen just by smelling the aroma of food from afar (Ferreira et al., 2021); (Zhang & Spence, 2023); (Girona-Ruíz et al., 2021).

Texture

Texture is the last factor seen by consumers after the appearance, color, smell, and taste of a food (Spence et al., 2022); (Pereira et al., 2021). Texture can be said to be

the final determinant of an assessment of food ingredients. When the texture is not good, then a food can be rejected or not consumed. The organoleptic test results showed that the immersion treatment did not have a significant effect on the organoleptic quality of tofu texture until the 3rd day. This indicates that the chitosan treatment was able to inhibit the organoleptic texture quality of tofu, so in other words, it is said that the integrity of tofu treated with chitosan solution can maintain the organoleptic texture quality of tofu (Jao et al., 2022). This can be seen in the samples soaked with chitosan with a concentration of 0.01% which are still firm and good.

Conclusion

From the results of the study entitled the edible coating application made from snail shell chitosan in an effort to maintain the quality and shelf life of tofu, the following conclusions were obtained: The results of the storage time test of chitosan-coated tofu showed that tofu soaked in chitosan solution with the addition of 0.01% kept the freshness until the 4th day; Organoleptic test results on chitosan-coated tofu showed that tofu soaked with chitosan solution with a concentration of 0.01% obtained good results compared to other concentrations, namely the smell was still good, the texture was still chewy and the color was still pure white.

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Author Contributions
Conceptualization; methodology.; validation; formal analysis; investigation; resources; A. A., T. S, data curation: writing—original draft preparation; m. I. E.; writing—review and editing.; visualization: G. F. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest
The authors declare no conflict of interest.

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