

BUKTI KORESPONDENSI
ARTIKEL JURNAL SINTA 2

Judul Artikel : Edible Coating Application Based On Snail Shell Chitosan In The Effort to Quality and Storage Of Tofu

Jurnal : Jurnal Penelitian Pendidikan IPA, Voloume 11597, Juli 2025 (e-ISSN: [2407-795X](#) p-ISSN: [2460-2582](#))

Penulis. : Andi Artiningsih, Takdir Syarif, Gusnawati, Febrian, Moh. Irsal Efendy

Jurnal. : <https://jppipa.unram.ac.id/index.php/jppipa/article/view/11597/7943>

No	Perihal	Tanggal
1	Bukti Konfirmasi submit artikel dan artikel yang	4 Juni 2025
2	Bukti Konfirmasi LOA (Accepted)	5 Juni 2025
3	Bukti konfirmasi Review-1	22 Juli 2025
4	Bukti Konfirmasi Perbaikan review	24 Juli 2025
5	Bukti Jurnal Publised	31 Juli 2025

1. BUKTI KONVIRMASI SUBMIT ARTIKEL
DAN ARTIKEL YANG DI SUBMIT

Jurnal Penelitian Pendidikan IPA



Submissions

My Queue 1

Archives

My Assigned

 Search

 Filter

11597 Artiningsih et al.

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Qu...

Submission

View

You are currently logged in as aartiningsih [Logout as aartiningsih](#)

Edit Profile

Logout as aartiningsih

2. BUKTI KONFIRMASI ACCEPTED

[Jurnal Penelitian Pendidikan IPA](#)

Tasks

aartiningsih

Submissions

My Queue 1 Archives

Help

My Assigned

Search

Filters [New Submission](#)

- 11597

Artiningsih et al.

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain
The Quality And Storage Of Tofu

Submission Currently in the Submission stage.

[View View Artiningsih et al.](#) Show more details about Artiningsih et al.

Help

Archived Submissions

Search

Filters [New Submission](#)

No submissions found.

[Table of Contents Close](#)

Loading

[Previous Next](#)

[Jurnal Penelitian Pendidikan IPA](#)

Tasks

aartiningsih

[← Back to Submissions](#)

11597 / Artiningsih et al. / Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu

Library

Workflow Publication

- [Submission](#)
- [Review](#)
- [Copyediting](#)
- [Production](#)

Submission Files

- [Search](#)

Name	Date	Component
Settings 63160 Edible coating blum di submit.docx	June 4, 2025	Article Text
Edit		

- [Download All Files](#)

Pre-Review Discussions

- [Add discussion](#)

Name From Last Reply Replies Closed

No Items

Status: Unscheduled

Title & Abstract Contributors Metadata References Galleys

Bahasa Indonesia English

Prefix

Examples: A, The

0/2 languages completed

Bahasa IndonesiaPrefix in Bahasa Indonesia

0/2 languages completed

Title

1/2 languages completed

Bahasa IndonesiaTitle in Bahasa Indonesia

1/2 languages completed

Subtitle

0/2 languages completed

Bahasa IndonesiaSubtitle in Bahasa Indonesia

0/2 languages completed

Abstract

The popularity of tofu is not only limited because it tastes good, but is also easy to make and can be processed into various forms of cooking at a low price. 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 application of chitosan as an edible coating on w'hite tofu is carried out in four stages, namely the preparation stage, immersion stage, storage stage, and testing stage. The preparation stage is carried nut 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 various concentrations of 0.5% 1°Xz and 1.5%c After that, the tofu storage stage is carried out at room temperature until there is a physical change to the tofu, the observation interval from day 0, day 1, to day 5 for the long test the effect of concentration on storage time. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition nf 0.01°Xo

1/2 languages completed

Bahasa IndonesiaAbstract in Bahasa Indonesia

1/2 languages completed

Save

List of Contributors

Name	E-mail	Role	Primary Contact In Browse Lists
Andi Artiningsih	andi.artiningsih@umi.ac.id	Author	

Name	E-mail	Role	Primary Contact In Browse Lists
Takdir syarif	andi.artiningsih@umi.ac.id	Author	
Gusnawati	andi.artiningsih@umi.ac.id	Author	
Febrian	andi.artiningsih@umi.ac.id	Author	
Moh. Irsal Efendy	andi.artiningsih@umi.ac.id	Author	

Bahasa Indonesia English

Keywords Keywords are typically one- to three-word phrases that are used to indicate the main topics of a submission.

Selected: None

0/2 languages completed

Bahasa IndonesiaKeywords in Bahasa IndonesiaKeywords are typically one- to three-word phrases that are used to indicate the main topics of a submission.

Selected: None

0/2 languages completed

Save

References

Enter each reference on a new line so that they can be extracted and recorded separately.

Save

Galleys

Name

No Items

[Table of Contents Close](#)

Loading

[Previous Next](#)



UNIVERSITAS
MATARAM
Jl. Majapahit No. 62 Mataram

Jurnal Penelitian
Pendidikan IPA
(JPPIPA)



Letter of Acceptance (LoA)

No. XI-7-11597/JPPIPA/2025

Based on the results of a review conducted by the Journal of Research in Science Education (Jurnal Penelitian Pendidikan IPA, e-ISSN: [2407-795X](#) p-ISSN: [2460-2582](#)) editorial team, hereby declare that:

Author : Andi Artiningsih, Takdir syarif, Gusnawati, Febrian, Moh. Irsal Efendy
Title : Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu
Decision : ACCEPTED
Date : 6/5/2025

The paper with the title above will be published in **Volume XI Issue 7, July 2025**

Thank you for your attention and cooperation.

Mataram, 6/5/2025

Editor in Chief

Prof. Aris Doyan, M.Si., Ph.D



Jurnal Penelitian Pendidikan IPA (JPPIPA)

Indexed on:



Jurnal Penelitian Pendidikan IPA (JPPIPA)
URL: <http://jppipa.unram.ac.id/index.php/jppipa/index>

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu

Andi Artiningsih¹, Takdir syarif², Gusnawati³, Febrian⁴, Moh, Irsal Efendy⁵

Chemical Engineering, Faculty of Industrial Technology, University of Muslim Indonesia

Autor: andi.artiningsih@umi.ac.id

Abstract

The popularity of tofu is not only limited because it tastes good, but is also easy to make and can be processed into various forms of cooking at a low price. 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 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 various concentrations of 0.5% and 1.5%. After that, the tofu storage stage is carried out at room temperature until there is a physical change to the tofu, the observation interval from day 0, day 1, to day 5 for the long test the effect of concentration on storage time. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition of 0.01% X

Key words: Chitosan, Chitin, Edible, Coating, Organoleptic Test, Tofu

1. 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 (Sa'diyah., 2020).

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 (Kartikorini, 2017). In order to prevent microbial growth that causes spoilage, some producers use synthetic preservatives and antioxidants such as formalin, benzoic acid, BHA (Butylated Hydroxyanisole), BHT (Butylated Hydroxytoluene) 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 (Waryat, et al. 2019). 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 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 (Hasrudin, et al. 2020).

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 (Naufalin, et al., 2018). 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. 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% (Pusparini, et al. 2018).

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 (Labagow, et al. 2019). 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.

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 days. Tofu can have longer shelf life if it is preserved by steaming or stored in a refrigerator for 1 day (Kartikorini, 2017). 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 (Pusparini, 2018).

Food technological advances have resulted new discoveries especially as a substitute for formaldehyde with the use of preservatives from natural ingredients. One example of a natural preservative which has a strong antimicrobial effect and can be used in food because it is non-toxic and safe for the human body is chitosan. 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 (Hartono, 2015).

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.

1. RESEARCH 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.

2.1 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

2.1.1 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 °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.

2.1.2 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

2.1.3 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.

2.2. 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.

2. RESULT AND DISCUSSION

3.1 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.

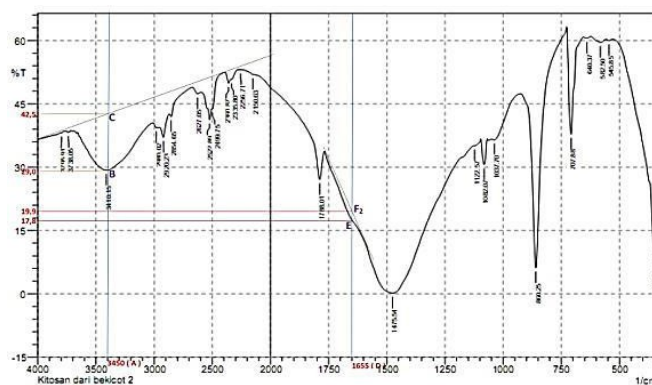


Figure 1. FTIR analysis results of snail shell chitosan

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 $\beta\text{-(1-4)-2-acetamide-deoxy-D-glucose}$ with NaOH.

3.2 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«	Texture	Color
0				
	2	+-	+-	+-
	3			
	4			
	5			
0,005%				
	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			
0,01%				
	2	+	+	+
	3	+	+	+
	4	+	+	+-
	5			
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. 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 Sudaryantiningsih and Pambudi (2018), 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 °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 (Dwi, et al., 2016).

3.3 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

Chitosan concentration	Day to	Observation Results		
		Aroma	Texture	Color
0	3	Rotten	Crushed and Watery	Brown
0,5	3	Rotten	Soft and Watery	Gloomy White
1	3	Good	Chewy and Good	Pure White
1,5	3	Smelly	Chewy and Watery	Yellow

3.3.1 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 (Arfah., 2001)

3.3.2 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 (Mead., 1964). 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 (Frazier dan Westhoff 1978).

3.3.3 Texture

Texture is the last factor seen by consumers after the appearance, color, smell, and taste of a food (Muchtadi., 1978). 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. This can be seen in the samples soaked with chitosan with a concentration of 0.01% which are still firm and good.

3. 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:

4.1 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.

- 4.2 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.

REFERENCES

- Arfah. (2001) Penerapan Kadaluausa Pangan. Bogor(ID): Departemen Ilmu dan Teknologi Pangan, Institut Pertanian Bogor.
- Dwi, Cahyono. And Purnomo, A. (2016) 'Perbandingan Kemampuan Kitosan Dari Limbah Kulit Udang Dengan Aluminium Sulfat Untuk Menurunkan Kekeruhan Air Dari Outlet Bak Prasedimentasi Ipam Ngagel li', *Jurnal Teknik Its*, 5(2).
- Frazier WC, DC Westhoff. (1978) Food microbiology. 3rd Edition. New Delhi: Hill Publishing Company Limited.
- Hartono, W. (2015) 'Berbisnis Bekicot (Siput) Dan Cara Pembudidayaannya', *Jurnal Stei Ekonomi*, 24(1), Pp. 1–16. Doi: 10.1017/Cbo9781107415324.004.
- Hasrudin, Karimuna, L. And Asyik, N. (2020) 'Analisis Kualitatif Kandungan Formalin Pada Tahu Yang Diperdagangkan Di Pasar Sentral Kota Dan Pasar Sentral Wua-Wua', *Jurnal Sains Dan Teknologi Pangan*, 5(1), Pp. 2725–2733.
- Kartikorini. N. (2017) ' Pengaruh Lama Perendaman Dengan Perasan Jeruk Lemon Dan Garam Dapur Terhadap Kadar Protein Tahu', *The Journal Of Muhammadiyah Medical Laboratory Technologis*, 2(1), Pp. 1- g.
- Labagow, E., Warouw, F. dan Akili, R. H. (2019) Kandungan Formalin in Pada Tahu Putih Di Pasar Pinasungkulan Karombasan Kota Manado 2019', *J urnal Kesmas*, 8(7), Pp. 67— 71.
- Mead GC. (1964) *Processing of poultry. London. Elsevier Applied Science*.
- Muchtadi TR. (2008) Teknologi Proses Pengolahan Bahan Pangan. Bogor: Fakultas Teknologi Pertanian. Institut Pertanian Bogor.
- Naufalin, R., Rukmini, H. S. dan Asril, P. (2018) 'Aplikasi Ekstrak Kecombrang (Nicolaia Speciosa) Sebagai Pengawet Alami Tahu Pada Perajin Tahu Di Sentra Industri Tahu Desa Kai isari Banyumas', *Jurnal Abdimas*, 22(2), Pp. 2(9)-214.
- Pusparini, I. D. And Triyanto, B. (2018) 'Deskripsi Kadar Formalin Pada Tahu Putih Yang Dijual Di Pasar Segamas Kabupaten Purbalingga Tahun 2017', *Buletin Keslingmas*, 37(2), Pp. 117–125. Doi: 10.31983/Keslingmas.V37i2.3834.
- Soekarto E. (1985) Penilaian Organoleptik untuk Pangan dan Hasil Pertanian. Jakarta: Bhartara Karya Aksara.
- Sudaryantiningih, C. And Pambudi, Y. S. (2018) 'Penerapan Eko-Efisiensi Pada Proses Pengemasan Tahu Dengan Penambahan Chitosan Untuk Memperpanjang Masa Simpan Tahu', *Jurnal Kesehatan Kusuma Husada*, Pp. 8–12. Doi: 10.34035/Jk.V9i1.253.
- Sa'diyah, K. (2020) 'Pembuatan Asap Cair Dari Pirolisis Serbuk Gergaji Kayu Jati Dan Aplikasinya Sebagai Pengawet Alami Tahu', In *Prosiding Seminar Nasional Rekayasa Proses Industri Kimia*, Pp. 3–5.
- Waryat, Neng Risris Sudolar, Miskiyah, Dan J. (2019) 'Aplikasi Vinegar Sebagai Pengawet Alami Untuk Meningkatkan Umur Simpan Tahu', *Urnal Ilmiah Respati*, 53(9), Pp. 1689–1699. Doi: 10.1017/Cbo9781107415324.004.
- Wahyuni, Ridhay, A. And Nurakhirawati (2016) Pengaruh Waktu Proses Deasetilasi Kitin Dari Cangkang Bekicot (Achatina Fulica) Terhadap Derajat Deasetilasi', *Kovalen*, 2(1), Pp. 1-7.

3. BUKTI KONFIRMASI REVIEW-1

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu

Andi Artiningsih¹, Takdir Syarif², Gusnawati³, Febrian⁴, Moh, Irsal Efendy⁵

Chemical Engineering, Faculty of Industrial Technology, University of Muslim Indonesia

Autor: andi.artiningsih@umi.ac.id

Abstract

The popularity of tofu is not only limited because it tastes good, but is also easy to make and can be processed into various forms of cooking at a low price. 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 application of chitosan as an edible coating on w'hite tofu is carried out in four stages, namely the preparation stage, immersion stage, storage stage, and testing stage. The preparation stage is carried nut 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 various concentrations of 0.5% 1"xz and 1.5%c Afler that, the tofu storage stage is carried out at room temperature until there is a physical change to the tofu, the observation interval from day 0, day 1, to day 5 for the long test the effect of concentration on storage time. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition nf 0.01"xo

Key words: Chitosan, Chitin, Edible, Coating, 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 (Sa'diyah., 2020).

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 (Kartikorini, 2017). 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 (Waryat, et al. 2019). Health department currently

Commented [R1]:

Book Antiqua 18pt,
Space 1,
Justify,
Capitalize each word except conjunctions,
not bold,

Commented [R2]:

Article is not in accordance with the format
Please process it according to the jppipa journal article format

writing articles using the book antiqua font, see examples of published journals

Commented [R3]:

Commented [R4]:

Commented [R5]:

Overly Detailed Introduction: The abstract begins with general information about tofu's popularity, taste, ease of making, and affordability. While true, this level of detail isn't necessary for an abstract, which should quickly get to the core of the research problem.

Repetitive and Redundant Problem Statement: Phrases like "Tofu also has a weakness, namely its high water content, making it easily damaged due to microbial growth" and "At room temperature, the average shelf life of young tofu is 1-2 days" convey similar information about spoilage. The statement about steaming and refrigeration only extending shelf life by 1 day contradicts the "1-2 days" average, creating confusion. The mention of "fraud" and "formalin" is critical but inserted somewhat abruptly and redundantly alongside the discussion of short shelf life.

Excessive Methodological Detail: Describing "The preparation stage is carried out by preparing all ingredients and tools..." is too granular for an abstract. The abstract needs to outline what was done, not how every preliminary step was executed.

Commented [R6]:

book antiqua, 9pt,
A concise and factual abstract (maximum length 200 words) is required. The abstract should briefly state the purpose, methods, results and discussion, and a concisely narrated conclusion.

Commented [R7]:

Book antiqua, 9pt, Replace commas with ;
Sort keywords alphabetically,
Keywords are in results and discussion

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 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 (Hasrudin, et al. 2020).

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 (Naufalin, et al., 2018). 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. 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% (Pusparini, et al. 2018).

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 (Labagow, et al. 2019). 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.

White tofu is a type of tofu produced and sold in the market. At room temperature, tofu has a shelf life of only 1-2 days. Tofu can have longer shelf life if it is preserved by steaming or stored in a refrigerator for 1 day (Kartikorini, 2017). 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 (Pusparini, 2018).

Food technological advances have resulted new discoveries especially as a substitute for formaldehyde with the use of preservatives from natural ingredients. 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. 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 (Hartono, 2015).

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.

2.1 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

2.1.3 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 °C. Once it was cool, it was filtered and neutralized with distilled water. The solid obtained was dried in

Commented [R8]: Join short paragraphs, fix the others

Commented [R9]: Sharpen this introduction, by explaining what is the novelty of this research? Give logical reasons why this research is important to do

Redundant Information and Repetitive Statements

Issue: The introduction repeatedly emphasizes the importance of food safety, the problem of tofu's short shelf life, and the illegal use of formalin.

Examples:

"Food plays a vital role in human survival. Therefore, it is necessary to ensure that the food consumed daily has a high level of safety..." (Paragraph 1) and "Food is one of the basic and primary needs of human life..." (Paragraph 1).

"One food safety issue that still requires supervision is the use of food additives..." (Paragraph 2) and "Currently, unfortunately, many tofu producers are engaging in manipulative practices... by adding preservatives such as formalin..." (Paragraph 5).

"Unfortunately, the high water content of tofu makes it prone to spoilage due to its easy growth of microbes." (Paragraph 5) and "At room temperature, tofu has a shelf life of only 1-2 days." (Paragraph 6).

Disorganized Flow and Lack of Logical Progression

Issue: The paragraphs jump between general food safety, the problem of illegal preservatives, specific data on formaldehyde in tofu (Hasrudin's study), then general information about tofu's popularity and nutritional value, then back to spoilage and formaldehyde, and finally to chitosan. This back-and-forth makes the argument hard to follow.

Overly Detailed Specific Examples and Citations Early On

Issue: Citing specific prices of tofu in Kalisari Village, Cilongok District (Naufalin, et al., 2018) or the exact NPU/digestibility percentages (Pusparini, et al. 2018) is too much detail for an introduction. While relevant background, it interrupts the flow of the problem statement. The specific formalin levels from Hasrudin's study are good evidence, but their placement could be more impactful.

Commented [R10]: 11pt, book antiqua, Capitalize each word

Commented [R11]: remove numbering 1, 2, 3,,, italic, not bold, Fix the others

an oven at 60°C until it was dry.

2.1.4 Demineralization

Deproteinized 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

2.1.3 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.

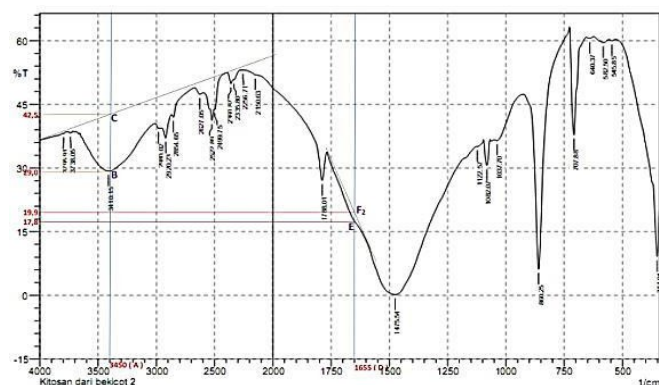
2.2. Proses edible coating

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.

4. RESULT AND DISCUSSION

3.4 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, the formation of a N atoms which have pair of free electrons attract protons to ammonium ion. To stabilize the N atom, bond is broken, accompanied by the formation of a C=O form chitosan (Wahyuni, et al., 2016). The results of the analysis of snail shell chitosan can be seen Figure 1 below.



causing
proton.
one
can
form
the N-C
bond to
2016).
FTIR
in

Commented [R12]: must be clear and it is recommended that there is a flow/chart.

Inconsistent and Vague Unit for Deacetylation Ratio

Issue: In the deacetylation step, you state, "NaOH 60% with a ratio of 20:1 (v/w)." While (v/w) typically means volume/weight, in the context of solids (NaOH solution) and solids (deacetylated chitin), it's ambiguous. Earlier steps use (v/w) for liquid/solid, and (v/h) is unusual. It's crucial to be precise about how this ratio is measured for reproducibility. If it's 20 mL of 60% NaOH solution per 1 gram of chitin, state it clearly.

Clarity on "Hong Method" for Chitin Purification

Issue: You state, "Purification of chitin is carried out using the Hong method in the following manner:" followed by a description of deproteination, demineralization, and deacetylation. While this outlines the steps, it's unclear if the "Hong Method" refers to the entire chitosan isolation process or specifically to the chitin purification before deacetylation. If it's a published method, referencing it with a citation here (e.g., "Hong's method (Hong et al., Years)") would be beneficial.

Redundancy in "Edible Coating Process" Preparation Step

Issue: "The preparation stage is carried out by preparing all the materials and tools that will be used in the soaking stage, storage stage and testing stage." This sentence is self-evident and doesn't add specific methodological information.

Ambiguous Concentration Unit for Edible Coating

Issue: You list concentrations as "0.005%, 0.01% and 0.015%." This implies percentage by weight or volume, but it's crucial to specify for accuracy (e.g., % (w/v) or % (w/w)). Given that chitosan is a solid, it's likely % (w/v) (weight of chitosan per volume of solvent).

Inconsistency in Observation Intervals

Issue: "The observation intervals start from Day 0, Day 1, and Day 5 (to test the effect of concentration on shelf life)." Observing only on Day 0, Day 1, and Day 5 seems insufficient to accurately determine the shelf life, especially if spoilage might occur between these intervals (e.g., on Day 2, 3, or 4). If the product lasts longer than 5 days, how is that captured?

Disjointed Organoleptic Testing Description

Issue: "Furthermore, organoleptic testing of tofu is carried out by soaking the tofu in one of the best concentrations, then storing it for 24 hours. Next, organoleptic tests are conducted covering the texture, aroma, color, and firmness ..."

Commented [R13]: fix the figure

Commented [R14]:

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.

3.5 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 $\ll$	Texture	Color
C	2	++	++	++
	3			
	4			
	5			
0,005%	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			
0,01%	2	+	+	+
	3	+	+	+

Commented [R15]: bold, fix the others

Commented [R16]: 9pt, book antiqua, fix the others

Commented [R17]: Bold, fix the others

Commented [R18]: Fix the other tables, try to see and follow the table rules according to JPPIPA.
the writing in the table is not bold, not italic, there are only 3 lines in the table, 2 lines above, 1 line below,
the size of the writing in the table is 9 pt, book antiqua, capital at the beginning of the word only, the first column is left aligned, the next column is right aligned, if there are numbers with commas, replace the comma with a dot, write 2 numbers behind the dot. Delete the number column, replace Indonesian with English.

0,015%	4	+	+	++
	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. 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 Sudaryantiningsih and Pambudi (2018), 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 °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 (Dwi, et al., 2016).

3.6 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

Chitosan concentration	Day to	Observation Results		
		Aroma	Texture	Color
0	3	Rotten	Crushed and Watery	Brown
0,5	3	Rotten	Soft and Watery	Gloomy White
1	3	Good	Chewy and Good	Pure White
1,5	3	Smelly	Chewy and Watery	Yellow

3.3.1 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 (Arfah., 2001)

3.3.2 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 (Mead., 1964). 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 (Frazier dan Westhof f 1978).

3.3.3 Texture

Texture is the last factor seen by consumers after the appearance, color, smell, and taste of a food (Muchtadi., 1978). 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. This can be seen in the samples soaked with chitosan with a concentration of 0.01% which are still firm and good.

5. 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:

Commented [R19]: Fix the other tables, try to see and follow the table rules according to JPPIPA.

the writing in the table is not bold, not italic, there are only 3 lines in the table, 2 lines above, 1 line below, the size of the writing in the table is 9 pt, book antiqua, capital at the beginning of the word only, the first column is left aligned, the next column is right aligned, if there are numbers with commas, replace the comma with a dot, write 2 numbers behind the dot. Delete the number column, replace Indonesian with English.

Commented [R20]:

tables, research images, data images must be clearer and must not be scans, there must be supporting literature that strengthens the research results. add some photos as the research progresses.

Inconsistent Data and Statements

Contradictory Statements Regarding Tofu's Perishability:

The first paragraph states: "Tofu soaked in a 0.01% chitosan solution can maintain its freshness up to the fourth day."

However, in Table 2 (Organoleptic Test of Tofu), for concentration "1" (assumed to be 0.01%), on Day 3, the tofu was still in "Good," "Chewy and Good," and "Pure White" condition. This supports the claim that the 0.01% tofu retains its freshness.

Then, in the organoleptic testing section, it is stated that the test was conducted up to the third day of storage. This raises the question: why are the results for shelf life up to the fourth day mentioned at the beginning if the organoleptic testing only lasted up to the third day?

Inconsistent Concentration Units:

In the text, the chitosan concentrations are stated as "0.01%," "0.005%," and "0.015%."

However, in Table 2, the concentrations listed are "0," "0.5," "1," and "1.5." This is very confusing. Does "0.5" mean 0.005%? And "1" means 0.01%? This should be explicitly explained or adjusted for consistency (e.g., use "0.005," "0.01," and "0.015" in the table).

Unclear Interpretation of Results

Cause of Deterioration on Day 5:

Statement: "On day 5, all tofu deteriorated, including the tofu at a concentration of 0.01%. This occurred because the edible coating used was saturated and could no longer adsorb to form a layer that could inhibit bacterial growth on the tofu samples."

- 4.3 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.
- 4.4 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.

REFERENCES

- Arfah. (2001) Penerapan Kadaluaarsa Pangan. Bogor(ID): Departemen Ilmu dan Teknologi Pangan, Institut Pertanian Bogor.
- Dwi, Cahyono. And Purnomo, A. (2016) 'Perbandingan Kemampuan Kitosan Dari Limbah Kulit Udang Dengan Aluminium Sulfat Untuk Menurunkan Kekeruhan Air Dari Outlet Bak Prasedimentasi Ipam Ngagel li', *Jurnal Teknik Its*, 5(2).
- Frazier WC, DC Westhoff. (1978) Food microbiology. 3rd Edition. New Delhi: Hill Publishing Company Limited.
- Hartono, W. (2015) 'Berbisnis Bekicot (Siput) Dan Cara Pembudidayanya', *Jurnal Stei Ekonomi*, 24(1), Pp. 1–16. Doi: 10.1017/Cbo9781107415324.004.
- Hasrudin, Karimuna, L. And Asyik, N. (2020) 'Analisis Kualitatif Kandungan Formalin Pada Tahu Yang Diperdagangkan Di Pasar Sentral Kota Dan Pasar Sentral Wua-Wua', *Jurnal Sains Dan Teknologi Pangan*, 5(1), Pp. 2725–2733.
- Kartikorini. N. (2017) ' Pengaruh Lama Perendaman Dengan Perasan Jeruk Lemon Dan Garam Dapur Terhadap Kadar Protein Tahu', *The Journal Of Muhammadiyah Medical Laboratory Technologis*, 2(1), Pp. 1- g.
- Labagow, E., Warouw, F. dan Akili, R. H. (2019) Kandungan Formalin Pada Tahu Putih Di Pasar Pinasungkulan Karombasan Kota Manado 2019', *Jurnal Kesmas*, 8(7), Pp. 67— 71.
- Mead GC. (1964) *Processing of poultry*. London. Elsevier Applied Science.
- Muchtadi TR. (2008) Teknologi Proses Pengolahan Bahan Pangan. Bogor: Fakultas Teknologi Pertanian. Institut Pertanian Bogor.
- Naufalin, R., Rukmini, H. S. dan Asril, P. (2018) 'Aplikasi Ekstrak Kecombrang (Nicolaia Speciosa) Sebagai Pengawet Alami Tahu Pada Perajin Tahu Di Sentra Industri Tahu Desa Kai isari Banyumas', *Jurnal Abdimas*, 22(2), Pp. 2()9-214.
- Pusparini, I. D. And Triyantoro, B. (2018) 'Deskripsi Kadar Formalin Pada Tahu Putih Yang Dijual Di Pasar Segamas Kabupaten Purbalingga Tahun 2017', *Buletin Keslingmas*, 37(2), Pp. 117–125. Doi: 10.31983/Keslingmas.V37i2.3834.
- Soekarto E. (1985) Penilaian Organoleptik untuk Pangan dan Hasil Pertanian. Jakarta: Bhratara Karya Aksara.
- Sudaryantiningasih, C. And Pambudi, Y. S. (2018) 'Penerapan Eko-Efisiensi Pada Proses Pengemasan Tahu Dengan Penambahan Chitosan Untuk Memperpanjang Masa Simpan Tahu', *Jurnal Kesehatan Kusuma Husada*, Pp. 8–12. Doi: 10.34035/Jk.V9i1.253.
- Sa'diyah, K. (2020) 'Pembuatan Asap Cair Dari Pirolisis Serbuk Gergaji Kayu Jat i Dan Aplikasinya Sebagai Pengawet Alami Tahu', In *Prosiding Seminar Nasional Rekayasa Proses Industri Kimia*, Pp. 3–5.
- Waryat, Neng Risris Sudolar, Miskiyah, Dan J. (2019) 'Aplikasi Vinegar Sebagai Pengawet Alami Untuk Meningkatkan Umur Simpan Tahu', *Urnal Ilmiah Respati*, 53(9), Pp. 1689–1699. Doi: 10.1017/Cbo9781107415324.004.
- Wahyuni, Ridhay, A. And Nurakhirawat i (2016) Pengaruh Waktu Proses Deasetilasi Kitin Dari Cangkang Bekicot (Achatina Fulica) Terhadap Derajat Deasetilasi', *Kovalen*, 2(1), Pp. 1-7.

Commented [R21]: narrate without numbering system 1), 2), check and correct the others with the same error

Commented [R22]:

After Conclusion add

Acknowledgments

Author Contributions/what is the role of each author, write their initials, for example (use initials): for example:

Conceptualization, C. H. S. A., P. M. Z., T. R., R. A. E., M. N. S.; methodology, C. H. S. A.; validation, P. M. Z. and T. R.; formal analysis, R. A. E.; investigation, M. N. S., and C. H. S. A.; resources, P. M. Z. and T. R.; data curation, R. A. E.: writing—original draft preparation, M. N. S and C. H. S. A.; writing—review and editing, P. M. Z.: visualization, and T. R. and R. A. E. All authors have read and agreed to the published version of the manuscript.

Funding

Conflicts of interest

Commented [R23]: Inconsistencies with Results and Discussion Data

Shelf Life Statement: Conclusion 4.1 states that "tofu soaked in a 0.01% chitosan solution maintained its freshness up to day 4." This is consistent with the "Results and Discussion" section, however, in the Organoleptic section, testing was only conducted up to day 3.

Quality and Quantity of Information Provided

Lack of Detail on Other Concentrations: Conclusion 4.1 focuses solely on 0.01%. While this is the best approach, the conclusion should also briefly mention how other concentrations (0.005% and 0.015%) performed to provide a more complete picture of the study.

Repetition of Organoleptic Information: Conclusion 4.2 over-details the organoleptic results (aroma, texture, color) that are already implicitly covered in 4.1 (with the phrase "freshness").

No Mention of Control: The conclusion does not mention ...

Commented [R24]: Insufficient references

Use journals with DOI

Minimum 40 citations/ references

20 citations from accredited national journals

10 citations from jppipa.unram.ac.id journals

10 citations from reputable international journals in Scopus

Additional citation results are included in the discussion to strengthen the research results

Bibliography APA (American Psychological Association Style)

4. BUKTI PERBAIKAN REVIEW- 2

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu

Andi Artiningsih¹, Takdir syarif², Gusnawati³, Febrian⁴, Moh, Irsal Efendy⁵

Chemical Engineering, Faculty of Industrial Technology, University of Muslim Indonesia

Autor: andi.artiningsih@umi.ac.id

Abstract

The popularity of tofu is not only limited because it tastes good, but is also easy to make and can be processed into various forms of cooking at a low price. 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 application of chitosan as an edible coating on w'hite tofu is carried out in four stages, namely the preparation stage, immersion stage, storage stage, and testing stage. The preparation stage is carried nut 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 various concentrations of 0.5% 1*Xz and 1.5%c After that, the tofu storage stage is carried out at room temperature until there is a physical change to the tofu, the observation interval from day 0, day 1, to day 5 for the long test the effect of concentration on storage time. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition nf 0.01*Xo

Key words: Chitosan, Chitin, Edible, Coating, Organoleptic Test, Tofu

6. 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 (Sa'diyah., 2020).

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 (Kartikorini, 2017). 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 (Waryat, et al. 2019). 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 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 (Hasrudin, et al. 2020).

Commented [u25]: Use template of JPPIPA.

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 (Naufalin, et al., 2018). 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. 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% (Pusparini, et al. 2018).

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 (Labagow, et al. 2019). 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.

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 days. Tofu can have longer shelf life if it is preserved by steaming or stored in a refrigerator for 1 day (Kartikorini, 2017). 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 (Pusparini, 2018).

Food technological advances have resulted new discoveries especially as a substitute for formaldehyde with the use of preservatives from natural ingredients. One example of a natural preservative which has a strong antimicrobial effect and can be used in food because it is non-toxic and safe for the human body is chitosan. 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 (Hartono, 2015).

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.

7. RESEARCH 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.

2.1 Chitosan isolation

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

2.1.5 Deproteinization

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 °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.

2.1.6 Demineralization

Deproteinized 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

2.1.3 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.

2.2. 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.

8. RESULT AND DISCUSSION

3.7 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 $\text{C}=\text{O}$ 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 $\text{C}=\text{O}$ 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.

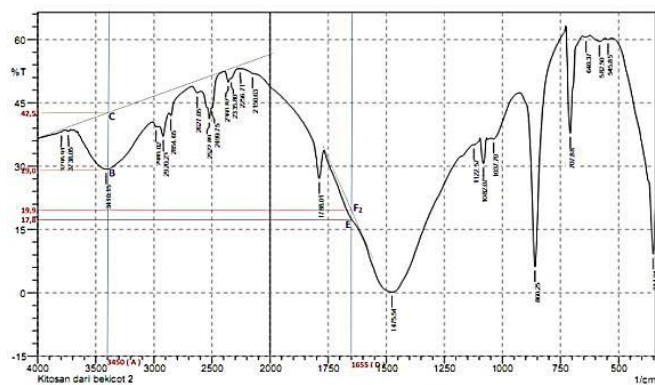


Figure 1. FTIR analysis results of snail shell chitosan

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 ($-\text{HCOCH}_3$) to an amine group ($-\text{NH}_2$). The deacetyl reaction is basically an amide hydrolysis reaction of β -(1-4)-2-acetamide-deoxy-D-glucose with NaOH.

3.8 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«	Texture	Color
0				
	2	+-	+-	+-
	3			
	4			
	5			
0,005%				
	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			
0,01%				
	2	+	+	+
	3	+	+	+
	4	+	+	+-
	5			
0,015%				
	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			

Commented [u26]: Use English format in writing number.

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. 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 Sudaryantiningih and Pambudi (2018), 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 °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 (Dwi, et al., 2016).

3.9 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

Chitosan concentration	Day to	Observation Results		
		Aroma	Texture	Color
0	3	Rotten	Crushed and Watery	Brown
0,5	3	Rotten	Soft and Watery	Gloomy White
1	3	Good	Chewy and Good	Pure White
1,5	3	Smelly	Chewy and Watery	Yellow

3.3.1 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 (Arfah., 2001)

3.3.2 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 (Mead., 1964). 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 (Frazier dan Westhoff 1978).

3.3.3 Texture

Texture is the last factor seen by consumers after the appearance, color, smell, and taste of a food (Muchtadi., 1978). 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. This can be seen in the samples soaked with chitosan with a concentration of 0.01% which are still firm and good.

9. CONCLUSION

Commented [u27]: Make it in 1 paragraph.

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:

- 4.5 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.
- 4.6 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.

REFERENCES

- Arfah. (2001) Penerapan Kadaluaarsa Pangan. Bogor(ID): Departemen Ilmu dan Teknologi Pangan, Institut Pertanian Bogor.
- Dwi, Cahyono. And Purnomo, A. (2016) 'Perbandingan Kemampuan Kitosan Dari Limbah Kulit Udang Dengan Aluminium Sulfat Untuk Menurunkan Kekeruhan Air Dari Outlet Bak Prasedimentasi Ipam Ngagel li', *Jurnal Teknik Its*, 5(2).
- Frazier WC, DC Westhoff. (1978) Food microbiology. 3rd Edition. New Delhi: Hill Publishing Company Limited.
- Hartono, W. (2015) 'Berbisnis Bekicot (Siput) Dan Cara Pembudidayaannya', *Jurnal Stei Ekonomi*, 24(1), Pp. 1–16. Doi: 10.1017/Cbo9781107415324.004.
- Hasrudin, Karimuna, L. And Asyik, N. (2020) 'Analisis Kualitatif Kandungan Formalin Pada Tahu Yang Diperdagangkan Di Pasar Sentral Kota Dan Pasar Sentral Wua-Wua', *Jurnal Sains Dan Teknologi Pangan*, 5(1), Pp. 2725–2733.
- Kartikorini. N. (2017) ' Pengaruh Lama Perendaman Dengan Perasan Jeruk Lemon Dan Garam Dapur Terhadap Kadar Protein Tahu', *The Journal Of Muhammadiyah Medical Laboratory Technologis*, 2(1), Pp. 1- g.
- Labagow, E., Warouw, F. dan Akili, R. H. (2019) Kandungan Formalin in Pada Tahu Putih Di Pasar Pinasungkulan Karombasan Kota Manado 2019', *Jurnal Kesmas*, 8(7), Pp. 67— 71.
- Mead GC. (1964) *Processing of poultry. London. Elsevier Applied Science*.
- Muchtadi TR. (2008) Teknologi Proses Pengolahan Bahan Pangan. Bogor: Fakultas Teknologi Pertanian. Institut Pertanian Bogor.
- Naufalin, R., Rukmini, H. S. dan Asril, P. (2018) 'Aplikasi Ekstrak Kecombrang (Nicotiana glauca) Sebagai Pengawet Alami Tahu Pada Perajin Tahu Di Sentra Industri Tahu Desa Kai isari Banyumas', *Jurnal Abdimas*, 22(2), Pp. 2(19-214).
- Pusparini, I. D. And Triyanto, B. (2018) 'Deskripsi Kadar Formalin Pada Tahu Putih Yang Dijual Di Pasar Segamas Kabupaten Purbalingga Tahun 2017', *Buletin Keslingmas*, 37(2), Pp. 117–125. Doi: 10.31983/Keslingmas.V37i2.3834.
- Soekarto E. (1985) Penilaian Organoleptik untuk Pangan dan Hasil Pertanian. Jakarta: Bhratara Karya Aksara.
- Sudaryantiningih, C. And Pambudi, Y. S. (2018) 'Penerapan Eko-Efisiensi Pada Proses Pengemasan Tahu Dengan Penambahan Chitosan Untuk Memperpanjang Masa Simpan Tahu', *Jurnal Kesehatan Kusuma Husada*, Pp. 8–12. Doi: 10.34035/Jk.V9i1.253.
- Sa'diyah, K. (2020) 'Pembuatan Asap Cair Dari Pirolisis Serbuk Gergaji Kayu Jati Dan Aplikasinya Sebagai Pengawet Alami Tahu', In *Prosiding Seminar Nasional Rekayasa Proses Industri Kimia*, Pp. 3–5.
- Waryat, Neng Risris Sudolar, Miskiyah, Dan J. (2019) 'Aplikasi Vinegar Sebagai Pengawet Alami Untuk Meningkatkan Umur Simpan Tahu', *Urnal Ilmiah Respati*, 53(9), Pp. 1689–1699. Doi: 10.1017/Cbo9781107415324.004.
- Wahyuni, Ridhay, A. And Nurakhiwati (2016) Pengaruh Waktu Proses Deasetilasi Kitin Dari Cangkang Bekicot (Achatina Fulica) Terhadap Derajat Deasetilasi', *Kovalen*, 2(1), Pp. 1-7.

Commented [u28]: Minimum 40 references.

Follow the writing format in the template.

Make sure all references are in the citation/quotation.

Add DOI or URL to each reference (see JPPIPA template on writing references).

The minimum number of references is 25 obtained from at least: 10 reputable international journals, and 15 accredited national journals.

The 25 references are recommended to be obtained from Sinta 2 accredited journals.

Reference writing uses APA format, for example:

Afriana, J., Permanasari, A., & Fitriani, A. (2016). Project based learning integrated to stem to enhance elementary school's students scientific literacy. *Jurnal Pendidikan IPA Indonesia*, 5(2), 261–267.

<https://doi.org/10.15294/jpii.v5i2.5493>

If using a URL, add the word Retrieved from before the URL

Edible Coating Application Based On Snail Shell Chitosan In The Effort To maintain The Quality And Storage Of Tofu

Commented [u29]: Use JPPIPA template and follow it.

Andi Artiningsih¹, Takdir syarif², Gusnawati³, Febrian⁴, Moh, Irsal Efendy⁵

Chemical Engineering, Faculty of Industrial Technology, University of Muslim Indonesia

Autor: andi.artiningsih@umi.ac.id

Abstract

The popularity of tofu is not only limited because it tastes good, but is also easy to make and can be processed into various forms of cooking at a low price. 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 application of chitosan as an edible coating on w'hite tofu is carried out in four stages, namely the preparation stage, immersion stage, storage stage, and testing stage. The preparation stage is carried nut 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 various concentrations of 0.5% 1"xz and 1.5%c. After that, the tofu storage stage is carried out at room temperature until there is a physical change to the tofu, the observation interval from day 0, day 1, to day 5 for the long test the effect of concentration on storage time. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition nf 0.01"xo

Key words: Chitosan, Chitin, Edible, Coating, Organoleptic Test, Tofu

10. 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 (Sa'diyah., 2020).

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 (Kartikorini, 2017). 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 (Waryat, et al. 2019). 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 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 (Hasrudin, et al. 2020).

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 (Naufalin, et al., 2018). 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. 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% (Pusparini, et al. 2018).

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 (Labagow, et al. 2019). 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.

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 days. Tofu can have longer shelf life if it is preserved by steaming or stored in a refrigerator for 1 day (Kartikorini, 2017). 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 (Pusparini, 2018).

Food technological advances have resulted new discoveries especially as a substitute for formaldehyde with the use of preservatives from natural ingredients. One example of a natural preservative which has a strong antimicrobial effect and can be used in food because it is non-toxic and safe for the human body is chitosan. 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 (Hartono, 2015).

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.

11. RESEARCH 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.

2.1 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

2.1.7 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 °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.

2.1.8 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

2.1.3 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.

2.2. 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.

12. RESULT AND DISCUSSION

3.10 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.

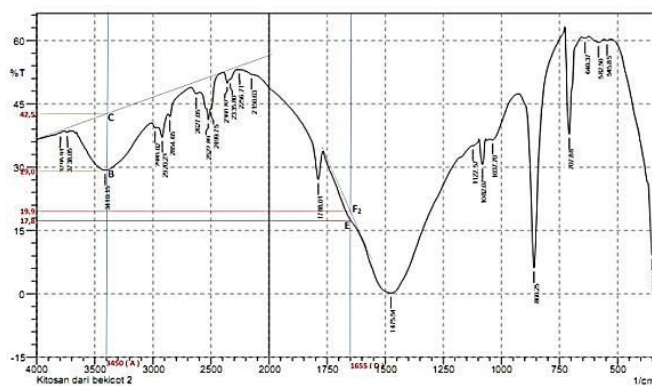


Figure 1. FTIR analysis results of snail shell chitosan

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.

3.11 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«	Texture	Color
0				
	2	+-	+-	+-
	3			
	4			
	5			
0,005%				
	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			
0,01%				
	2	+	+	+
	3	+	+	+
	4	+	+	+-
	5			
0,015%				
	2	+	+	+
	3	+	+	+
	4	+-	+	+
	5			

Commented [u30]: 0.005
Fix the other.

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. 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 Sudaryantiningsih and Pambudi (2018), 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 °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 (Dwi, et al., 2016).

3.12 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

Chitosan concentration	Day to	Observation Results		
		Aroma	Texture	Color
0	3	Rotten	Crushed and Watery	Brown
0,5	3	Rotten	Soft and Watery	Gloomy White
1	3	Good	Chewy and Good	Pure White
1,5	3	Smelly	Chewy and Watery	Yellow

3.3.1 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 (Arfah., 2001)

3.3.2 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 (Mead., 1964). 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 (Frazier dan Westhoff 1978).

3.3.3 Texture

Texture is the last factor seen by consumers after the appearance, color, smell, and taste of a food (Muchtadi., 1978). 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. This can be seen in the samples soaked with chitosan with a concentration of 0.01% which are still firm and good.

13. 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:

- 4.7 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.
- 4.8 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.

REFERENCES

- Arfah. (2001) Penerapan Kadaluarsa Pangan. Bogor(ID): Departemen Ilmu dan Teknologi Pangan, Institut Pertanian Bogor.
- Dwi, Cahyono. And Purnomo, A. (2016) 'Perbandingan Kemampuan Kitosan Dari Limbah Kulit Udang Dengan Aluminium Sulfat Untuk Menurunkan Kekeruhan Air Dari Outlet Bak Prasedimentasi Ipam Ngagel II', *Jurnal Teknik Its*, 5(2).
- Frazier WC, DC Westhoff. (1978) Food microbiology. 3rd Edition. New Delhi: Hill Publishing Company Limited.
- Hartono, W. (2015) 'Berbisnis Bekicot (Siput) Dan Cara Pembudidayaannya', *Jurnal Stei Ekonomi*, 24(1), Pp. 1–16. Doi: 10.1017/Cbo9781107415324.004.
- Hasrudin, Karimuna, L. And Asyik, N. (2020) 'Analisis Kualitatif Kandungan Formalin Pada Tahu Yang Diperdagangkan Di Pasar Sentral Kota Dan Pasar Sentral Wua-Wua', *Jurnal Sains Dan Teknologi Pangan*, 5(1), Pp. 2725–2733.
- Kartikorini. N. (2017) ' Pengaruh Lama Perendaman Dengan Perasan Jeruk Lemon Dan Garam Dapur Terhadap Kadar Protein Tahu', *The Journal Of Muhammadiyah Medical Laboratory Technologis*, 2(1), Pp. 1- g.
- Labagow, E., Warouw, F. dan Akili, R. H. (2019) Kandungan Formalin Pada Tahu Putih Di Pasar Pinasungkulan Karombasan Kota Manado 2019', *Jurnal Kesmas*, 8(7), Pp. 67— 71.
- Mead GC. (1964) *Processing of poultry*. London. Elsevier Applied Science.
- Muchtadi TR. (2008) Teknologi Proses Pengolahan Bahan Pangan. Bogor: Fakultas Teknologi Pertanian. Institut Pertanian Bogor.
- Naufalin, R., Rukmini, H. S. dan Asril, P. (2018) 'Aplikasi Ekstrak Kecombrang (Nicotiana glauca) Sebagai Pengawet Alami Tahu Pada Perajin Tahu Di Sentra Industri Tahu Desa Kai Isari Banyumas', *Jurnal Abdimas*, 22(2), Pp. 2(9)-214.
- Pusparini, I. D. And Triyantor, B. (2018) 'Deskripsi Kadar Formalin Pada Tahu Putih Yang Dijual Di Pasar Segamas Kabupaten Purbalingga Tahun 2017', *Buletin Keslingmas*, 37(2), Pp. 117–125. Doi: 10.31983/Keslingmas.V37i2.3834.
- Soekarto E. (1985) Penilaian Organoleptik untuk Pangan dan Hasil Pertanian. Jakarta: Bhartara Karya Aksara.
- Sudaryantiningih, C. And Pambudi, Y. S. (2018) 'Penerapan Eko-Efisiensi Pada Proses Pengemasan Tahu Dengan Penambahan Chitosan Untuk Memperpanjang Masa Simpan Tahu', *Jurnal Kesehatan Kusuma Husada*, Pp. 8–12. Doi: 10.34035/Jk.V9i1.253.
- Sa'diyah, K. (2020) 'Pembuatan Asap Cair Dari Pirolisis Serbuk Gergaji Kayu Jati Dan Aplikasinya Sebagai Pengawet Alami Tahu', In *Prosiding Seminar Nasional Rekayasa Proses Industri Kimia*, Pp. 3–5.
- Waryat, Neng Riris Sudolar, Miskiyah, Dan J. (2019) 'Aplikasi Vinegar Sebagai Pengawet Alami Untuk Meningkatkan Umur Simpan Tahu', *Urnal Ilmiah Respati*, 53(9), Pp. 1689–1699. Doi: 10.1017/Cbo9781107415324.004.
- Wahyuni, Ridhay, A. And Nurakhiwati (2016) Pengaruh Waktu Proses Deasetilasi Kitin Dari Cangkang Bekicot (Achatina Fulica) Terhadap Derajat Deasetilasi', *Kovalen*, 2(1), Pp. 1-7.

Commented [u31]: Must summarize all the results and discussions in this study briefly. Make it in 1 paragraph.

Commented [u32]: Use APA style. Minimum 40 references accompanied by doi/url. All references must be in sync with the citation.

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

Andi Artiningsih¹, Takdir syarif¹, Gusnawati¹, Febrian¹, Moh, Irsal Efendy¹

¹Chemical Engineering, Faculty of Industrial Technology, Universitas Muslim Indonesia, Makassar, Indonesia

Received:
Revised:
Accepted:
Published:

Corresponding Author*:
Andi Artiningsih
andi.artiningsih@umi.ac.id

© 2025 The Authors. This open-access article is distributed under a (CC-BY License)



DOI:

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% 1^o The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition of 0.01% X_o.

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); (Raðu 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 Hydroxyanisole), BHT (Butylated Hydroxytoluene) 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 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., 2023a); (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 (Džugan 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 & Nagababu, 2022); (Rathee et al., 2023b).. 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 °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

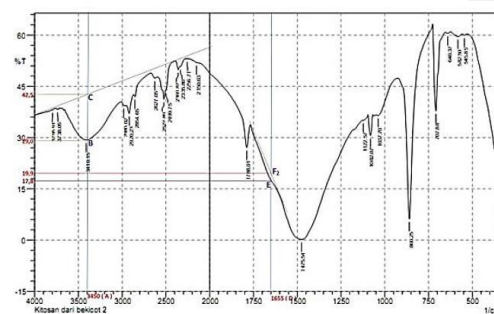
The application of chitosan as an edible coating on white tofu is carried out through four stages, namely the preparation stage, the soaking stage, the storage stage, and the testing stage. The preparation stage was carried out by preparing all the materials and tools that will be used in the immersion 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:



group (-NH₂). 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 (Smutek & 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 °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

Chitosan concentration	Day to	Aroma	Observation Results	
			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-Ruiz 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.

Acknowledgments

Thanks to all parties who have supported the implementation of this research. I hope this research can be useful.

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.

Funding

Researchers independently funded this research.

Conflicts of Interest

The authors declare no conflict of interest.

References

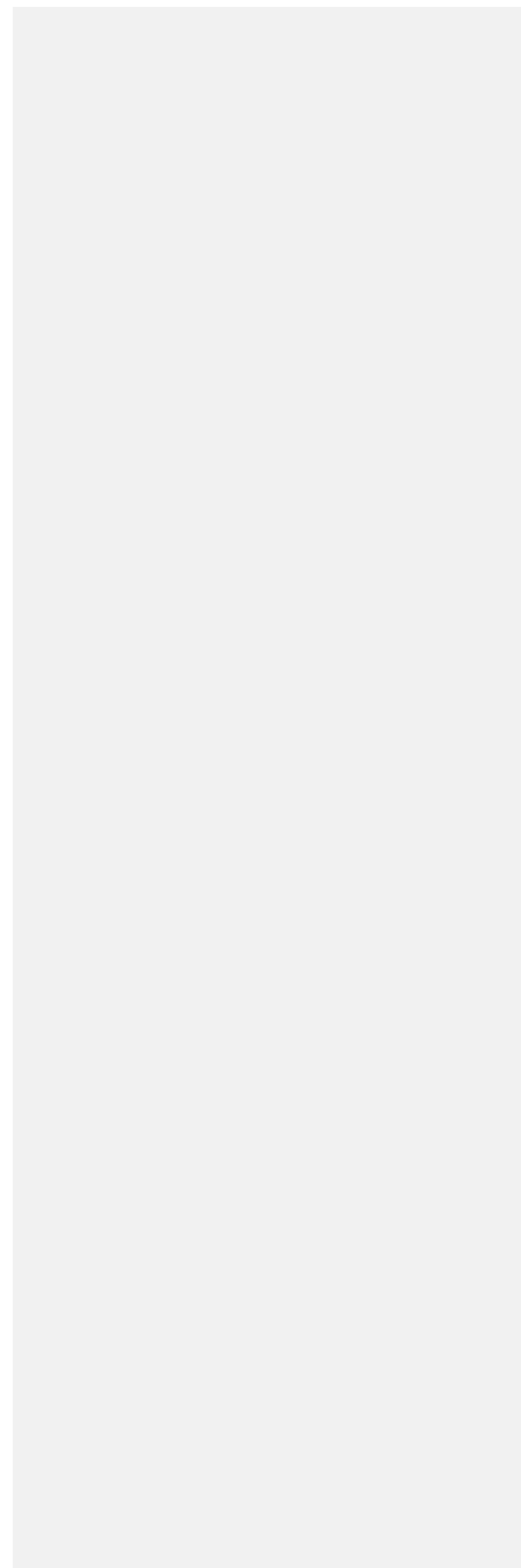
- Al-Maqtari, Q. A., Alkawry, T. A. A., Odjo, K., Al-Gheethi, A. A. S., Ghamry, M., Mahdi, A. A., Al-Ansi, W., & Yao, W. (2023). Improving the shelf life of tofu using chitosan/gelatin-based films incorporated with *Pulicaria jaubertii* extract microcapsules. *Progress in Organic Coatings*, 183, 107722. <https://doi.org/10.1016/j.porgcoat.2023.107722>
- Andreani, G., Sogari, G., Marti, A., Frolidi, F., Dagevos, H., & Martini, D. (2023). Plant-Based Meat Alternatives: Technological, Nutritional, Environmental, Market, and Social Challenges and Opportunities. *Nutrients*, 15(2), 452. <https://doi.org/10.3390/nu15020452>
- Chen, H., Lin, B., Zhang, R., Gong, Z., Wen, M., Su, W., Zhou, J., Zhao, L., & Wang, J. (2022). Controllable preparation of chitosan oligosaccharides via a recombinant chitosanase from marine *Streptomyces lydicus* S1 and its potential application on preservation of pre-packaged tofu. *Frontiers in Microbiology*, 13. <https://doi.org/10.3389/fmicb.2022.100720>
- Dai, Z., Han, L., Li, Z., Gu, M., Xiao, Z., & Lu, F. (2022). Combination of Chitosan, Tea Polyphenols, and Nisin on the Bacterial Inhibition and Quality Maintenance of Plant-Based Meat. *Foods*, 11(10), 1524. <https://doi.org/10.3390/foods11101524>
- Dey, S., & Nagababu, B. H. (2022). Applications of food color and bio-preservatives in the food and its effect on the human health. *Food Chemistry Advances*, 1, 100019. <https://doi.org/10.1016/j.focha.2022.100019>
- Dżugan, M., Tomczyk, M., Szymański, P., Grabek-Lejko, D., & Miłek, M. (2024). The Influence of Selected Herb Additives on the Organoleptic and Antioxidant Properties and Storage Stability of Frozen Homemade Tofu. *Applied Sciences*, 14(15), 6801. <https://doi.org/10.3390/app14156801>
- Ferreira, V., de-la-Fuente-Blanco, A., & Sáenz-Navajas, M.-P. (2021). A New Classification of Perceptual Interactions between Odorants to Interpret Complex Aroma Systems. Application to Model Wine Aroma. *Foods*, 10(7), 1627. <https://doi.org/10.3390/foods10071627>
- Fletcher, B., Mullane, K., Platts, P., Todd, E., Power, A., Roberts, J., Chapman, J., Cozzolino, D., & Chandra, S. (2018). Advances in meat spoilage detection: A short focus on rapid methods and technologies. *CyTA - Journal of Food*, 16(1), 1037–1044. <https://doi.org/10.1080/19476337.2018.1525432>
- Geng, Y., Du, X., Jia, R., Zhu, Y., Lu, Y., Guan, X., Hu, Y., Zhu, X., & Zhang, M. (2024). Research Progress on Tofu Coagulants and Their Coagulation Mechanisms. *Foods*, 13(21), 3475. <https://doi.org/10.3390/foods13213475>
- Girona-Ruiz, D., Cano-Lamadrid, M., Carbonell-Barrachina, Á. A., López-Lluch, D., & Esther, S. (2021). Aromachology Related to Foods, Scientific Lines of Evidence: A Review. *Applied Sciences*, 11(13), 6095. <https://doi.org/10.3390/app11136095>
- Guzmán-Soto, I., McTiernan, C., Gonzalez-Gomez, M., Ross, A., Gupta, K., Suuronen, E. J., Mah, T.-F., Griffith, M., & Alarcon, E. I. (2021). Mimicking biofilm formation and development: Recent progress in in vitro and in vivo biofilm models. *iScience*, 24(5), 102443. <https://doi.org/10.1016/j.isci.2021.102443>
- Hammer, L., Moretti, D., Bétrix, C.-A., Kandiah, P., Pellegrini, A., Abbühl-Eng, L., Portmann, R., & Egger, L. (2024). In vitro DIAAS of Swiss soybean cultivars using the INFOGEST model: Increase in protein quality from soybean to soymilk and tofu. *Food Research International*, 178, 113947.

- <https://doi.org/10.1016/j.foodres.2024.113947>
- Jao, C.-H., Lin, C.-Y., Chen, C.-J., & Hsieh, J.-F. (2022). Effects of Calcium Sulfate and Chitosan on Textural Modification and Microstructure of Tofu Made from Lentils (*Lens culinaris*). *Processes*, 10(10), 2000. <https://doi.org/10.3390/pr10102000>
- Karnwal, A., Kumar, G., Singh, R., Selvaraj, M., Malik, T., & Al Tawaha, A. R. M. (2025). Natural biopolymers in edible coatings: Applications in food preservation. *Food Chemistry: X*, 25, 102171. <https://doi.org/10.1016/j.fochx.2025.102171>
- Kobayashi, R., Ishiguro, T., Ozeki, A., Kawai, K., & Suzuki, T. (2020). Property changes of frozen soybean curd during frozen storage in “Kori-tofu” manufacturing process. *Food Hydrocolloids*, 104, 105714. <https://doi.org/10.1016/j.foodhyd.2020.105714>
- Lobiuc, A., Pavăl, N.-E., Mangalagiu, I. I., Gheorghiu, R., Teliban, G.-C., Amăriucăi-Mantu, D., & Stoleru, V. (2023). Future Antimicrobials: Natural and Functionalized Phenolics. *Molecules*, 28(3), 1114. <https://doi.org/10.3390/molecules28031114>
- Mafe, A. N., Edo, G. I., Makia, R. S., Joshua, O. A., Akpogheli, P. O., Gaaz, T. S., Jikah, A. N., Yousif, E., Isoje, E. F., Igbuku, U. A., Ahmed, D. S., Essaghah, A. E. A., & Umar, H. (2024). A review on food spoilage mechanisms, food borne diseases and commercial aspects of food preservation and processing. *Food Chemistry Advances*, 5, 100852. <https://doi.org/10.1016/j.focha.2024.100852>
- Nabila, R., Sulistyarti, H., Wisang, Y. F., & Sabarudin, A. (2019). Determination of Formaldehyde in Tofu by Sequential Injection Analysis Using Acetoacetanilide as Hantzsch Reaction Reagent. *IOP Conference Series: Materials Science and Engineering*, 546(3), 032024. <https://doi.org/10.1088/1757-899x/546/3/032024>
- Nkansah, M. A., Agyei, E. A., & Opoku, F. (2021). Mineral and proximate composition of the meat and shell of three snail species. *Heliyon*, 7(10), e08149. <https://doi.org/10.1016/j.heliyon.2021.e08149>
- Paramasivam, A., Murugan, R., Jeraud, M., Dakkumadugula, A., Periyasamy, R., & Arjunan, S. (2024). Additives in Processed Foods as a Potential Source of Endocrine-Disrupting Chemicals: A Review. *Journal of Xenobiotics*, 14(4), 1697–1710. <https://doi.org/10.3390/jox14040090>
- Pereira, T., Barroso, S., & Gil, M. M. (2021). Food Texture Design by 3D Printing: A Review. *Foods*, 10(2), 320. <https://doi.org/10.3390/foods10020320>
- Pérez-Marroquín, X. A., Estrada-Fernández, A. G., García-Ceja, A., Aguirre-Álvarez, G., & León-López, A. (2023). Agro-Food Waste as an Ingredient in Functional Beverage Processing: Sources, Functionality, Market and Regulation. *Foods*, 12(8), 1583. <https://doi.org/10.3390/foods12081583>
- Prima Arumsari, G., Krianto, T., & Wispriyono, B. (2017). Behaviour of Traders And Manufacturers In The Use Of Formalin In Wet Noodle And Tofu In Jakarta. *Jurnal Kesehatan Masyarakat Andalas*, 11(1), 39–48. <https://doi.org/10.24893/jkma.v11i1.261>
- Punia Bangar, S., Chaudhary, V., Thakur, N., Kajla, P., Kumar, M., & Trif, M. (2021). Natural Antimicrobials as Additives for Edible Food Packaging Applications: A Review. *Foods*, 10(10), 2282. <https://doi.org/10.3390/foods10102282>
- Rahman, Md. B., Hussain, M., Kabiraz, M. P., Nordin, N., Siddiqui, S. A., Bhowmik, S., & Begum, M. (2023). An update on formaldehyde adulteration in food: Sources, detection, mechanisms, and risk assessment. *Food Chemistry*, 427, 136761. <https://doi.org/10.1016/j.foodchem.2023.136761>
- Rathee, P., Sehrawat, R., Rathee, P., Khatkar, A., Akkol, E. K., Khatkar, S., Redhu, N., Türkcanoğlu, G., & Sobarzo-Sánchez, E. (2023a). Polyphenols: Natural Preservatives with Promising Applications in Food, Cosmetics and Pharma Industries; Problems and Toxicity Associated with Synthetic Preservatives; Impact of Misleading Advertisements; Recent Trends in Preservation and Legislation. *Materials*, 16(13), 4793. <https://doi.org/10.3390/ma16134793>

- Rathee, P., Sehrawat, R., Rathee, P., Khatkar, A., Akkol, E. K., Khatkar, S., Redhu, N., Türkcanoglu, G., & Sobarzo-Sánchez, E. (2023b). Polyphenols: Natural Preservatives with Promising Applications in Food, Cosmetics and Pharma Industries; Problems and Toxicity Associated with Synthetic Preservatives; Impact of Misleading Advertisements; Recent Trends in Preservation and Legislation. *Materials*, 16(13), 4793. <https://doi.org/10.3390/ma16134793>
- Raţu, R. N., Veleşcu, I. D., Stoica, F., Usturoi, A., Arsenoaia, V. N., Crivei, I. C., Postolache, A. N., Lipşa, F. D., Filipov, F., Florea, A. M., Chiţea, M. A., & Brumă, I. S. (2023). Application of Agri-Food By-Products in the Food Industry. *Agriculture*, 13(8), 1559. <https://doi.org/10.3390/agriculture13081559>
- Razzak, A., Mahjabin, T., Khan, M. R. M., Hossain, M., Sadia, U., & Zzaman, W. (2023). Effect of cooking methods on the nutritional quality of selected vegetables at Sylhet City. *Heliyon*, 9(11), e21709. <https://doi.org/10.1016/j.heliyon.2023.e21709>
- Recoules, C., Touvier, M., Pierre, F., & Audebert, M. (2025). Evaluation of the toxic effects of food additives, alone or in mixture, in four human cell models. *Food and Chemical Toxicology*, 196, 115198. <https://doi.org/10.1016/j.fct.2024.115198>
- Román-Doval, R., Torres-Arellanes, S. P., Tenorio-Barajas, A. Y., Gómez-Sánchez, A., & Valencia-Lazcano, A. A. (2023). Chitosan: Properties and Its Application in Agriculture in Context of Molecular Weight. *Polymers*, 15(13), 2867. <https://doi.org/10.3390/polym15132867>
- Saget, S., Costa, M., Santos, C. S., Vasconcelos, M. W., Gibbons, J., Styles, D., & Williams, M. (2021). Substitution of beef with pea protein reduces the environmental footprint of meat balls whilst supporting health and climate stabilisation goals. *Journal of Cleaner Production*, 297, 126447. <https://doi.org/10.1016/j.jclepro.2021.126447>
- Shaik, M. I., Azhari, M. F., & Sarbon, N. M. (2022). Gelatin-Based Film as a Color Indicator in Food-Spoilage Observation: A Review. *Foods*, 11(23), 3797. <https://doi.org/10.3390/foods11233797>
- Sheffield, S., Fiorotto, M. L., & Davis, T. A. (2024). Nutritional importance of animal-sourced foods in a healthy diet. *Frontiers in Nutrition*, 11. <https://doi.org/10.3389/fnut.2024.1424912>
- Smulek, W., & Kaczorek, E. (2022). Factors Influencing the Bioavailability of Organic Molecules to Bacterial Cells—A Mini-Review. *Molecules*, 27(19), 6579. <https://doi.org/10.3390/molecules27196579>
- Spence, C., Motoki, K., & Petit, O. (2022). Factors influencing the visual deliciousness / eye-appeal of food. *Food Quality and Preference*, 102, 104672. <https://doi.org/10.1016/j.foodqual.2022.104672>
- Thaivalappil, A., Jung, J., Sekercioglu, F., & Young, I. (2025). Factors influencing food safety and good manufacturing practices in ready-to-eat meat processing plants in Ontario, Canada: A qualitative study. *Food and Humanity*, 4, 100538. <https://doi.org/10.1016/j.foohum.2025.100538>
- Thamsborg, K. K. M., Lund, B. W., Byrne, D. V., Leisner, J. J., & Alexi, N. (2023). Cadaverine as a Potential Spoilage Indicator in Skin-Packed Beef and Modified-Atmosphere-Packed Beef. *Foods*, 12(24), 4489. <https://doi.org/10.3390/foods12244489>
- Yadav, H., Malviya, R., & Kaushik, N. (2024). Chitosan in biomedicine: A comprehensive review of recent developments. *Carbohydrate Polymer Technologies and Applications*, 8, 100551. <https://doi.org/10.1016/j.carpta.2024.100551>
- Zhang, T., & Spence, C. (2023). Orthonasal olfactory influences on consumer food behaviour. *Appetite*, 190, 107023. <https://doi.org/10.1016/j.appet.2023.107023>

.

5. BUKTI PUBLISHED





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

Andi Artiningsih^{1*}, Takdir Syarif¹, Gusnawati¹, Febrian¹, Moh. Irsal Efendy¹

¹Chemical Engineering, Faculty of Industrial Technology, Universitas Muslim Indonesia, Makassar, Indonesia.

Received: April 22, 2025

Revised: June 04, 2025

Accepted: July 25, 2025

Published: July 31, 2025

Corresponding Author:

Andi Artiningsih

andi.artiningsih@umi.ac.id

DOI: [10.29303/jppipa.v11i7.11597](https://doi.org/10.29303/jppipa.v11i7.11597)

© 2025 The Authors. This open-access article is distributed under a (CC-BY License)



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 storage time is 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% 1°. The results of the long storage test for tofu coated with chitosan showed that the tofu soaked with chitosan solution with the addition of 0.01%.

Keywords: Chitin; Chitosan; 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; Raṭu 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 Hydroxyanisole), BHT (Butylated Hydroxytoluene) and TBHQ (Tertiary 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 Agent*). Tofu is one type of traditional food that is widely consumed by the community and often contains

How to Cite:

Artiningsih, A., syarif, T., Gusnawati, Febrian, & Efendy, M. I. (2025). Edible Coating Application Based on Snail Shell Chitosan in the Effort to Maintain the Quality and Storage of Tofu. *Jurnal Penelitian Pendidikan IPA*, 11(7), 371–377. <https://doi.org/10.29303/jppipa.v11i7.11597>

formaldehyde. Based on the result of study conducted by Hasrudin et al. (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 (Džugan 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 (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 & 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; 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.

Deproteinization

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 °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

Deproteinized 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. The results of the FTIR analysis of snail shell chitosan can be seen in Figure 1.

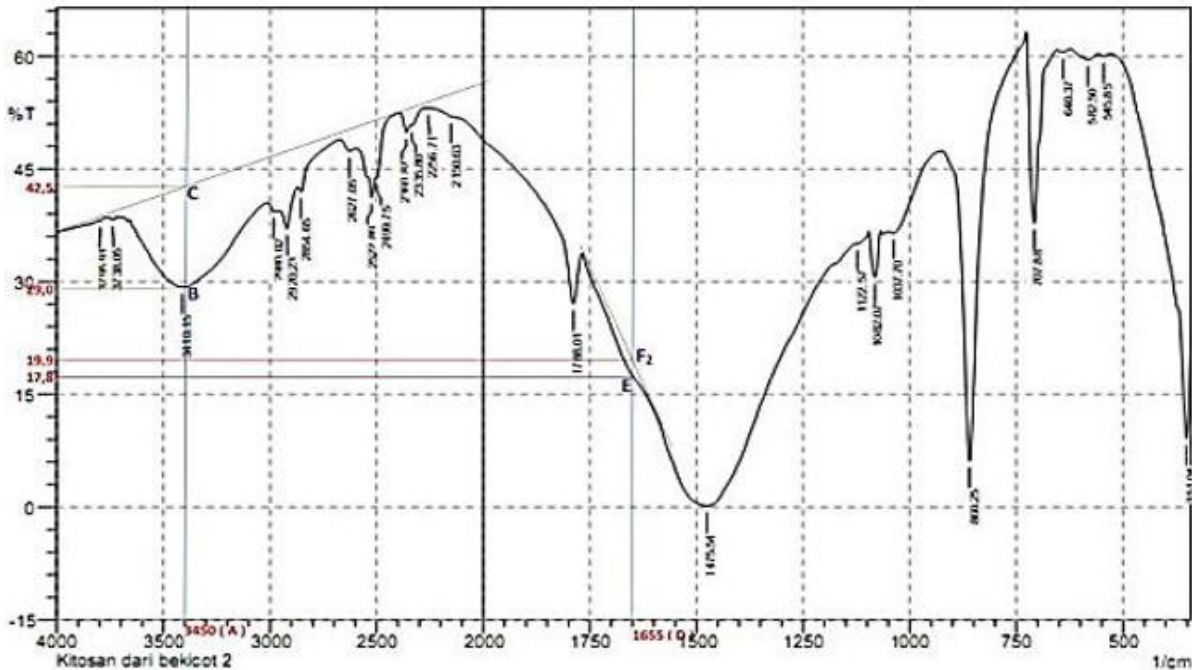


Figure 1. FTIR analysis results of snail shell chitosan

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 (-HCOCH₃) to an amine group (-NH₂). 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.

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 & 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), and 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 °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 is shown in Table 2.

Table 2. Tofu organoleptic test

Chitosan concentration	Day to	Observation Results		
		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-Ruiz 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.

Acknowledgments

Thanks to all parties who have supported the implementation of this research. I hope this research can be useful.

Author Contributions

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

Funding

Researchers independently funded this research.

Conflicts of Interest

The authors declare no conflict of interest.

References

- Al-Maqtari, Q. A., Alkawry, T. A. A., Odjo, K., Al-Gheethi, A. A. S., Ghamry, M., Mahdi, A. A., Al-Ansi, W., & Yao, W. (2023). Improving the Shelf Life of Tofu Using Chitosan/Gelatin-Based Films Incorporated with *Pulicaria jaubertii* Extract Microcapsules. *Progress in Organic Coatings*, 183, 107722. <https://doi.org/10.1016/j.porgcoat.2023.107722>
- Andreani, G., Sogari, G., Marti, A., Frolidi, F., Dagevos, H., & Martini, D. (2023). Plant-Based Meat Alternatives: Technological, Nutritional, Environmental, Market, and Social Challenges and Opportunities. *Nutrients*, 15(2), 452. <https://doi.org/10.3390/nu15020452>
- Arumsari, G. P., Krianto, T., & Wispriyono, B. (2017). Behaviour of Traders and Manufacturers in The Use of Formalin in Wet Noodle and Tofu in Jakarta. *Jurnal Kesehatan Masyarakat Andalas*, 11(1), 39–48. <https://doi.org/10.24893/jkma.v11i1.261>
- Bangar, S. P., Chaudhary, V., Thakur, N., Kajla, P., Kumar, M., & Trif, M. (2021). Natural Antimicrobials as Additives for Edible Food Packaging Applications: A Review. *Foods*, 10(10), 2282. <https://doi.org/10.3390/foods10102282>
- Chen, H., Lin, B., Zhang, R., Gong, Z., Wen, M., Su, W., Zhou, J., Zhao, L., & Wang, J. (2022). Controllable Preparation of Chitosan Oligosaccharides via a Recombinant Chitosanase from Marine *Streptomyces lydicus* S1 and Its Potential Application on Preservation of Pre-Packaged Tofu. *Frontiers in Microbiology*, 13. <https://doi.org/10.3389/fmicb.2022.1007201>
- Dai, Z., Han, L., Li, Z., Gu, M., Xiao, Z., & Lu, F. (2022). Combination of Chitosan, Tea Polyphenols, and

- Nisin on the Bacterial Inhibition and Quality Maintenance of Plant-Based Meat. *Foods*, 11(10), 1524. <https://doi.org/10.3390/foods11101524>
- Dey, S., & Nagababu, B. H. (2022). Applications of Food Color and Bio-Preservatives in the Food and Its Effect on the Human Health. *Food Chemistry Advances*, 1, 100019. <https://doi.org/10.1016/j.focha.2022.100019>
- Dżugan, M., Tomczyk, M., Szymański, P., Grabek-Lejko, D., & Miłek, M. (2024). The Influence of Selected Herb Additives on the Organoleptic and Antioxidant Properties and Storage Stability of Frozen Homemade Tofu. *Applied Sciences*, 14(15), 6801. <https://doi.org/10.3390/app14156801>
- Ferreira, V., de-la-Fuente-Blanco, A., & Sáenz-Navajas, M.-P. (2021). A New Classification of Perceptual Interactions between Odorants to Interpret Complex Aroma Systems. Application to Model Wine Aroma. *Foods*, 10(7), 1627. <https://doi.org/10.3390/foods10071627>
- Fletcher, B., Mullane, K., Platts, P., Todd, E., Power, A., Roberts, J., Chapman, J., Cozzolino, D., & Chandra, S. (2018). Advances in Meat Spoilage Detection: A Short Focus on Rapid Methods and Technologies. *CyTA - Journal of Food*, 16(1), 1037–1044. <https://doi.org/10.1080/19476337.2018.1525432>
- Geng, Y., Du, X., Jia, R., Zhu, Y., Lu, Y., Guan, X., Hu, Y., Zhu, X., & Zhang, M. (2024). Research Progress on Tofu Coagulants and Their Coagulation Mechanisms. *Foods*, 13(21), 3475. <https://doi.org/10.3390/foods13213475>
- Girona-Ruíz, D., Cano-Lamadrid, M., Carbonell-Barrachina, Á. A., López-Lluch, D., & Esther, S. (2021). Aromachology Related to Foods, Scientific Lines of Evidence: A Review. *Applied Sciences*, 11(13), 6095. <https://doi.org/10.3390/app11136095>
- Guzmán-Soto, I., McTiernan, C., Gonzalez-Gomez, M., Ross, A., Gupta, K., Suuronen, E. J., Mah, T.-F., Griffith, M., & Alarcon, E. I. (2021). Mimicking Biofilm Formation and Development: Recent Progress in In Vitro and In vivo Biofilm Models. *iScience*, 24(5), 102443. <https://doi.org/10.1016/j.isci.2021.102443>
- Hammer, L., Moretti, D., Bétrix, C.-A., Kandiah, P., Pellegrini, A., Abbühl-Eng, L., Portmann, R., & Egger, L. (2024). In Vitro DIAAS of Swiss Soybean Cultivars Using the INFOGEST Model: Increase in Protein Quality from Soybean to Soymilk and Tofu. *Food Research International*, 178, 113947. <https://doi.org/10.1016/j.foodres.2024.113947>
- Hasrudin, H., Karimuna, L., & Asyik, N. (2020). Analisis Kualitatif dan Kuantitatif Kandungan Formalin pada Tahu yang Diperdagangkan di Pasar Sentral Kota dan Pasar Sentral Wua-Wua. *Jurnal Sains dan Teknologi Pangan*, 5(1). <http://dx.doi.org/10.33772/jstp.v5i1.11553>
- Jao, C.-H., Lin, C.-Y., Chen, C.-J., & Hsieh, J.-F. (2022). Effects of Calcium Sulfate and Chitosan on Textural Modification and Microstructure of Tofu Made from Lentils (*Lens culinaris*). *Processes*, 10(10), 2000. <https://doi.org/10.3390/pr10102000>
- Karnwal, A., Kumar, G., Singh, R., Selvaraj, M., Malik, T., & Al Tawaha, A. R. M. (2025). Natural Biopolymers in Edible Coatings: Applications in Food Preservation. *Food Chemistry: X*, 25, 102171. <https://doi.org/10.1016/j.fochx.2025.102171>
- Kobayashi, R., Ishiguro, T., Ozeki, A., Kawai, K., & Suzuki, T. (2020). Property Changes of Frozen Soybean Curd During Frozen Storage in “Kori-Tofu” Manufacturing Process. *Food Hydrocolloids*, 104, 105714. <https://doi.org/10.1016/j.foodhyd.2020.105714>
- Lobiuc, A., Pavăl, N.-E., Mangalagiu, I. I., Gheorghită, R., Teliban, G.-C., Amăriucăi-Mantu, D., & Stoleru, V. (2023). Future Antimicrobials: Natural and Functionalized Phenolics. *Molecules*, 28(3), 1114. <https://doi.org/10.3390/molecules28031114>
- Mafe, A. N., Edo, G. I., Makia, R. S., Joshua, O. A., Akpogheli, P. O., Gaaz, T. S., Jikah, A. N., Yousif, E., Isoje, E. F., Igbuku, U. A., Ahmed, D. S., Essaghah, A. E. A., & Umar, H. (2024). A Review on Food Spoilage Mechanisms, Food Borne Diseases and Commercial Aspects of Food Preservation and Processing. *Food Chemistry Advances*, 5, 100852. <https://doi.org/10.1016/j.focha.2024.100852>
- Nabila, R., Sulistyarti, H., Wisang, Y. F., & Sabarudin, A. (2019). Determination of Formaldehyde in Tofu by Sequential Injection Analysis Using Acetoacetanilide as Hantzsch Reaction Reagent. *IOP Conference Series: Materials Science and Engineering*, 546(3), 032024. <https://doi.org/10.1088/1757-899x/546/3/032024>
- Nkansah, M. A., Agyei, E. A., & Opoku, F. (2021). Mineral and Proximate Composition of the Meat and Shell of Three Snail Species. *Heliyon*, 7(10), e08149. <https://doi.org/10.1016/j.heliyon.2021.e08149>
- Paramasivam, A., Murugan, R., Jeraud, M., Dakkumadugula, A., Periyasamy, R., & Arjunan, S. (2024). Additives in Processed Foods as a Potential Source of Endocrine-Disrupting Chemicals: A Review. *Journal of Xenobiotics*, 14(4), 1697–1710. <https://doi.org/10.3390/jox14040090>
- Pereira, T., Barroso, S., & Gil, M. M. (2021). Food Texture Design by 3D Printing: A Review. *Foods*, 10(2), 320. <https://doi.org/10.3390/foods10020320>
- Pérez-Marroquín, X. A., Estrada-Fernández, A. G., García-Ceja, A., Aguirre-Álvarez, G., & León-López, A. (2023). Agro-Food Waste as an Ingredient

- in Functional Beverage Processing: Sources, Functionality, Market and Regulation. *Foods*, 12(8), 1583. <https://doi.org/10.3390/foods12081583>
- Rahman, Md. B., Hussain, M., Kabiraz, M. P., Nordin, N., Siddiqui, S. A., Bhowmik, S., & Begum, M. (2023). An Update on Formaldehyde Adulteration in Food: Sources, Detection, Mechanisms, and Risk Assessment. *Food Chemistry*, 427, 136761. <https://doi.org/10.1016/j.foodchem.2023.136761>
- Rathee, P., Sehrawat, R., Rathee, P., Khatkar, A., Akkol, E. K., Khatkar, S., Redhu, N., Türkcanoğlu, G., & Sobarzo-Sánchez, E. (2023). Polyphenols: Natural Preservatives with Promising Applications in Food, Cosmetics and Pharma Industries; Problems and Toxicity Associated with Synthetic Preservatives; Impact of Misleading Advertisements; Recent Trends in Preservation and Legislation. *Materials*, 16(13), 4793. <https://doi.org/10.3390/ma16134793>
- Rațu, R. N., Veleșcu, I. D., Stoica, F., Usturoi, A., Arsenoaia, V. N., Crivei, I. C., Postolache, A. N., Lipșa, F. D., Filipov, F., Florea, A. M., Chițea, M. A., & Brumă, I. S. (2023). Application of Agri-Food By-Products in the Food Industry. *Agriculture*, 13(8), 1559. <https://doi.org/10.3390/agriculture13081559>
- Razzak, A., Mahjabin, T., Khan, M. R. M., Hossain, M., Sadia, U., & Zzaman, W. (2023). Effect of Cooking Methods on the Nutritional Quality of Selected Vegetables at Sylhet City. *Heliyon*, 9(11), e21709. <https://doi.org/10.1016/j.heliyon.2023.e21709>
- Recoules, C., Touvier, M., Pierre, F., & Audebert, M. (2025). Evaluation of the Toxic Effects of Food Additives, Alone or in Mixture, in Four Human Cell Models. *Food and Chemical Toxicology*, 196, 115198. <https://doi.org/10.1016/j.fct.2024.115198>
- Román-Doval, R., Torres-Arellanes, S. P., Tenorio-Barajas, A. Y., Gómez-Sánchez, A., & Valencia-Lazcano, A. A. (2023). Chitosan: Properties and Its Application in Agriculture in Context of Molecular Weight. *Polymers*, 15(13), 2867. <https://doi.org/10.3390/polym15132867>
- Saget, S., Costa, M., Santos, C. S., Vasconcelos, M. W., Gibbons, J., Styles, D., & Williams, M. (2021). Substitution of Beef with Pea Protein Reduces the Environmental Footprint of Meat Balls Whilst Supporting Health and Climate Stabilisation Goals. *Journal of Cleaner Production*, 297, 126447. <https://doi.org/10.1016/j.jclepro.2021.126447>
- Shaik, M. I., Azhari, M. F., & Sarbon, N. M. (2022). Gelatin-Based Film as a Color Indicator in Food-Spoilage Observation: A Review. *Foods*, 11(23), 3797. <https://doi.org/10.3390/foods11233797>
- Sheffield, S., Fiorotto, M. L., & Davis, T. A. (2024). Nutritional Importance of Animal-Sourced Foods in a Healthy Diet. *Frontiers in Nutrition*, 11. <https://doi.org/10.3389/fnut.2024.1424912>
- Smułek, W., & Kaczorek, E. (2022). Factors Influencing the Bioavailability of Organic Molecules to Bacterial Cells—A Mini-Review. *Molecules*, 27(19), 6579. <https://doi.org/10.3390/molecules27196579>
- Spence, C., Motoki, K., & Petit, O. (2022). Factors Influencing the Visual Deliciousness/Eye-Appeal of Food. *Food Quality and Preference*, 102, 104672. <https://doi.org/10.1016/j.foodqual.2022.104672>
- Thaivalappil, A., Jung, J., Sekercioglu, F., & Young, I. (2025). Factors Influencing Food Safety and Good Manufacturing Practices in Ready-to-Eat Meat Processing Plants in Ontario, Canada: A Qualitative Study. *Food and Humanity*, 4, 100538. <https://doi.org/10.1016/j.fooohum.2025.100538>
- Thamsborg, K. K. M., Lund, B. W., Byrne, D. V., Leisner, J. J., & Alexi, N. (2023). Cadaverine as a Potential Spoilage Indicator in Skin-Packed Beef and Modified-Atmosphere-Packed Beef. *Foods*, 12(24), 4489. <https://doi.org/10.3390/foods12244489>
- Yadav, H., Malviya, R., & Kaushik, N. (2024). Chitosan in Biomedicine: A Comprehensive Review of Recent Developments. *Carbohydrate Polymer Technologies and Applications*, 8, 100551. <https://doi.org/10.1016/j.carpta.2024.100551>
- Zhang, T., & Spence, C. (2023). Orthonasal Olfactory Influences on Consumer Food Behaviour. *Appetite*, 190, 107023. <https://doi.org/10.1016/j.appet.2023.107023>