Evaluation of the nutritional quality of fermented cultivated Patin Surimi (Pangasius sutchi) with various salt concentration and fermentation time

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Abstract. Patin is a tropical fish in South Kalimantan. The use of cultivated patin is still limited. Patin is processed into surimi and fermented so has no bones, no skin, little fat, and high protein. The aim of this research is to evaluate the nutritional quality of fermented cultivated patin surimi with various salt concentrations and fermentation times. Patin surimi is added with roasted rice in a ratio of 1:2 and fermented with various salt concentrations (5, 10, and 15%) and fermentation times (0 – 7 days). The results obtained showed that lactic acid bacteria could grow spontaneously quickly at a salt concentration of 5% from day 3 to day 7, whereas at salt concentrations of 10% and 15% the growth of lactic acid bacteria was very slow. The nutritional changes in fermented cultivated patin surimi are moisture content 57.21 – 43.25%, ash content 2.91 – 10.72%, protein content 18.98 – 29.07%, fat content 0.17 – 2 %, pH 6.42 – 5.62, total titrated acid 0.18 – 0.56%, and total salt 6.85 – 14.47%. Based on this, the best of fermented cultivated patin surimi is at a salt concentration of 5% and a fermentation time of 5 days.

1 Introduction

Patin is a South Kalimantan cultivated fish. The production of this fish in South Kalimantan in 2022 will be 4300 tons [1]. Patin contains a lot of fat, thick skin, bones, and red flesh. The use of patin is limited to being used as fresh fish by frying, grilling or dipping it. The high fat content, especially in the skin and meat, that the use of patin fish meat is still limited. Therefore, the fatty part of the patin is reduced by making the patin into surimi. The cultivated patin surimi contains 1.0 to 2.4% fat and patin fat is 3.75%. Apart from that, the meat form patin surimi also no fishy and muddy and the color become yellowish white [2].

Cultivated patin surimi is fermented spontaneously to produce hydrolyzed surimi, especially the protein part into peptides and amino acids [3]. This hydrolysis process makes patin surimi produced easier to digest when consumed. Because fermented cultivated patin surimi is good for use in food for children and adults. Apart from that, fermented patin surimi

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can be used to produce various practical and healthy food products, such as processing it into shredded meat.

Microorganisms that grow during spontaneous fermentation under anaerobic conditions according to [4] are lactic acid bacteria which are homofermentative proteolytic, such as Lactobacillus plantarum, Lacobacillus pentosus, and Pediococcus pentosaceus. The lactic acid bacteria identified in tilapia fish, namely Lactobacillus plantarum, also have amylolytic and lipolytic properties [5]. The presence of lactic acid bacteria influences the characteristics of fermented cultivated patin surimi metabolites.

The resulting fermented cultivated patin surimi product has a different taste, aroma and texture from patin meat before fermentation. According to [6], the color of fermented fish meat is pinkish, increasing the umami and sour aroma, as well as a texture that is easy to chew or juiciness. Apart from that, fermentation also functions to increase the nutritional content of simpler food ingredients, such as the formation of peptides, amino acids and free fatty acids. With the function of the fermentation process like this, many people in all parts of the world produce fermented products spontaneously by adding salt [7].

The aim of this research was to evaluate the nutritional quality of fermented cultivated patin surimi with various salt concentrations and fermentation times. The benefit of this research is that there is a product without bones and skin, does not smell like fish, is low in fat, easy to digest, easy to chew, and has an umami and sour aroma. Apart from that, the product produced is a healthy food for children and adults, because it is easy to digest.

2 Methodologhy

2.1 Material

The cultivated patin was collest from Cindai Alus Village, Banjar Regency, South Kalimantan (-3.397326645906731 latitude and 114.78946666331959 longitude). We used 500 g fish and 30 cm of fish length.

2.2 Surimi Processing

Surimi processing is carried out by modifying method [2]. Cultivated patin are cleaned, washed and filleted (slicing the fish lengthwise from the back). Fish fillets are separated from the flesh, skin and spines by scraping. The meat is washed, ground, and washed again with cold water (4 - 5 repetitions). The patin meat that has been washed is then pressed. The result is called cultivated patin surimi.

2.3 Cultivated Patin Surimi Fermentation

Fermentation of cultivated patin surimi is modified from the traditional processing of bekasam in the Banjarmasin city and modified from [4, 8, 9]. Cultivated patin surimi was added with NaCl with several concentrations (5%, 10%, and 15%) and incubated in a closed container for 15 minutes at room temperature. After that, roasted rice is added with the ratio between cultivated patin surimi and roasted rice being 1 : 2. The mixture is put into a container and closed tightly for the fermentation process. Fermentation was carried out for 7 days at room temperature (27 – 30oC). Observations were made on days 0, 1, 2, 3, 4, 5, 6, and 7.

2.4 Total Lactic Acid Bacteria

Total lactic acid bacteria were counted by modifying methods [8] and [5]. The total plate count (TPC) is used to determine the total LAB (Lactic Acid Bacteria). The total LAB calculation was carried out by calculating the total LAB grown on Man Rogosa and Sharpe Agar (MRSA) culture media. The TPC test used is the pour method. A sample of 1 gram is first taken and then ground to make it homogeneous. Then the sample was diluted and 9 ml NaCl solution (10^{-1}) was added. Next, take 1 ml of the sample that has been diluted and then put it into 25 ml of MRSA media in a petri dish. Next, the petri dish containing the media and sample is shaken in the shape of the number 8. After that, it is left for 1-2 hours until it hardens, then the petri dish is turned over and put into the incubator. Leave it for 48 hours until LAB grows and observe every 24 hours at 37ºC. The total LAB calculation is as follows:

$$\text{Total Bacteria} = \text{Total colonies x } \frac{1}{\text{Dilution Factor}} \quad (1)$$

2.5 Proximate Chemical Analysis

Observations were made by observing moisture content [9], fat content [10], protein content [11], pH, total titrated acid [12], and ash content [13].

2.6 Salt Content (Mohr Method)

The chopped sample was dissolved in 1 g in a 250 ml volumetric flask then blended. The sample solution that has been blended is then filtered and put into an erlenmeyer flask. 10 ml of the filtered sample was taken, then dripped with 0.5 ml of 2% K_2CrO_4 solution as an indicator and titrated with a standard 0.1 N $AgNO_3$ solution until a brick red color was formed [14]. Then the amount of $AgNO_3$ used is recorded. The salt content of the sample can be calculated by:

$$\text{Salt Content (\%)} = \frac{V\text{AgNO3 x NAgNO3 x BE NaCl x DF x 100\%}}{\text{mg sample}} \quad (2)$$

Note:
BE NaCl = massa molar 58,44 g/mol
DF = Dilution Factor = 25

3 Result

3.1 Total Lactic Acid Bacteria

Total lactic acid bacteria (LAB) in fermentation with salt concentration of 5% began to increase on day 4, namely 1.75×10^8 CFU/g up to day 7 to 4.79×10^8 CFU/g. In fact, on day 3, the total LAB of fermented cultivated patin surimi was only 7.14×10^6 CFU/g (Figure 1). The total growth pattern of LAB in fermentation with salt concentration of 5% was the same as fermentation with salt concentration of 15%. The increase in total LAB for a salt concentration of 15% began to occur on day 5 to 1.67×10^4 CFU/g from 4.56×10^3 CFU/g. This increase in total LAB until day 7 was 4.45×10^5 CFU/g (Figure 1).

A different pattern occurred in the fermented cultivated patin surimi with salt concentration of 10%. Total LAB increased on day 5 from 1.45×10^5 CFU/g to 2.9×10^6 CFU/g, and on the 6th day total LAB decreased drastically to 1.27×10^6 CFU/g and on the 7th day the total LAB decreased to 9.3×10^5 CFU/g.

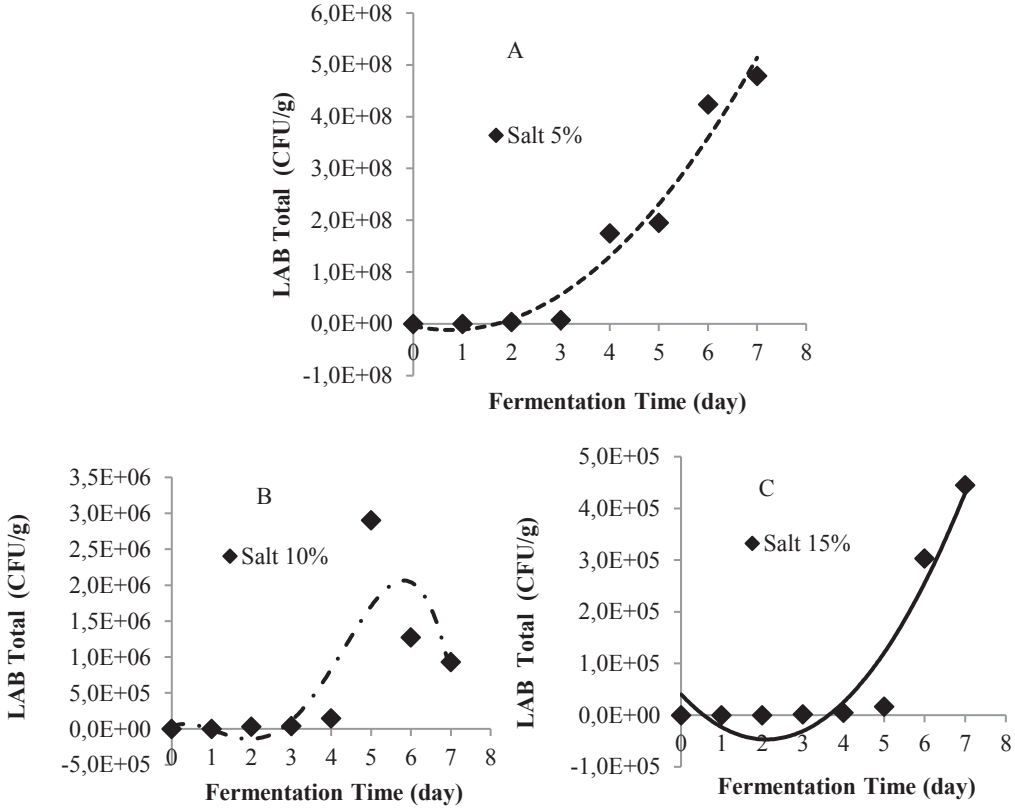

Fig. 1. Total lactic acid bacteria for fermented cultivated patin surimi for 7 days. A. Salt content 5%, B. Salt content 10%, and C. Salt content 15%.

3.2 Moisture Content

The water content of fermented cultivated patin surimi during 7 days of fermentation decreased by 5 to 14% from the initial moisture content of 57.21% (Figure 2). The slowest decrease in moisture content occurred in fermented cultivated patin surimi with the addition of 5% salt, namely 5% (Figure 2). If the salt concentration is increased to 10% or 15%, the decrease in moisture content will be sharper, namely 10 – 14% (Figure 2). Even fermenting cultivated patin surimi with salt concentration of 15%, the moisture content of fermented cultivated patin surimi continued to decrease for 7 days. As for the surimi fermentation of cultivated patin with the salt concentration of 5% or 10%, the decrease in moisture content occurs more slowly until the 5th day. After the 5th day the moisture content tends to level off. Even though there was an increase in moisture content, the increase in moisture content was very small (Figure 2).

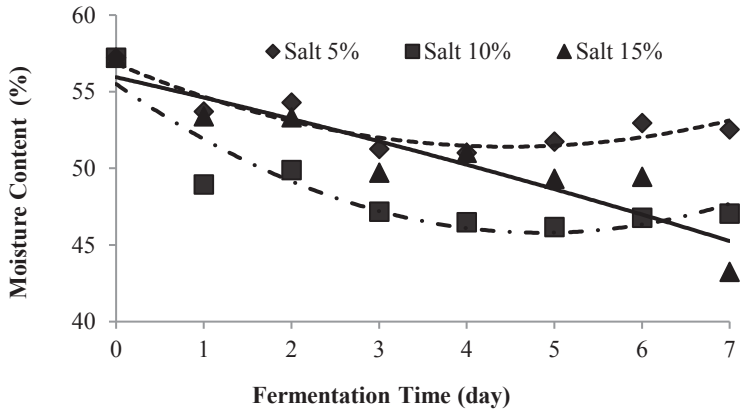

Fig. 2. Moisture content of fermented cultivated patin surimi for 7 days with various salt concentrations.

3.3 Fat Content

The fat content of fermented cultivated patin surimi for 7 days increased from 0.37% to 2.34% (Figure 3). Based on research [2] the fat content of cultivated surimi patin is 1.0 to 2.4%. This fat content is smaller than the fat content of whole cultivated patin fish which is 3.75%. The decrease in fat content in cultivated patin surimi is due to the washing process in making surimi causing the fat part bound to protein to dissolve in the washing water.

The fat content of fermented cultivated patin surimi increases with the longer fermentation and the greater salt concentration added. The increase in fat content of fermented cultivated patin surimi with a salt concentration of 5% for 7 days was 0.5%. However, if the salt concentration added for fermenting cultivated patin surimi is higher, namely 10% and 15%, then the fat content can increase by around 1.7 to 2% until the 7th day of fermentation.

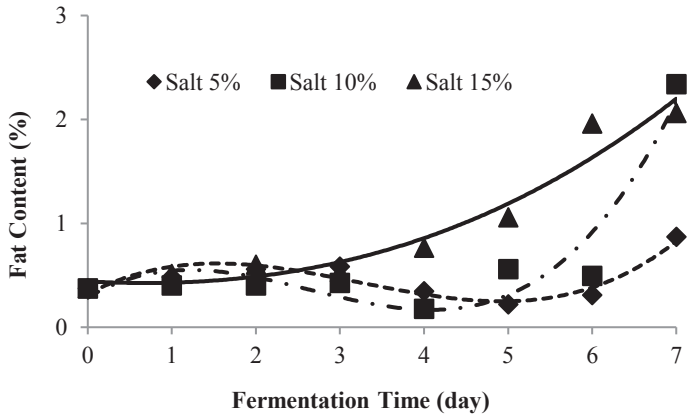

Fig. 3. Fat content of fermented cultivated patin surimi for 7 days with various salt concentrations.

3.4 Protein Content

The protein content of fermented cultivated patin surimi ranged from 18.98% to 29.07% with a moisture content of 43 - 57% (Figure 4). This protein content is higher than the protein content of cultivated patin surimi without fermentation is 5.6 – 7.9% with a moisture content of 84 – 86% [2].

During the 7 days of the fermentation process, there was an increase in the protein content of fermented cultivated patin surimi by 2 to 9% (Figure 4). The higher salt concentration added to fermented cultivated patin surimi, the higher protein content of patin surimi will increase during fermentation process. This is in line with [15] which stated that there was an increase in the protein content of wadi patin with the greater salt concentration added, namely 5% to 10%, with fermentation for 24 hours.

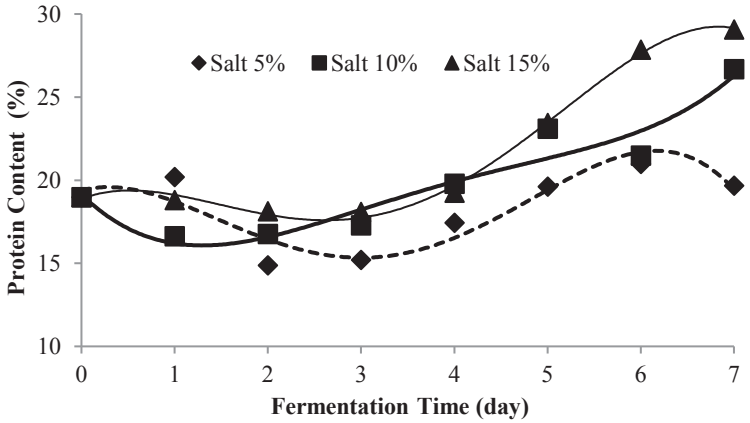

Fig. 4. Protein content of fermented cultivated patin surimi for 7 days with various salt concentrations

3.5 pH

The degree of acidity (pH) is one of the parameters that shows the acidity level of a material. Changes in pH values in fermented cultivated patin surimi can be seen in Figure 5.

There is a decrease in the pH value in cultivated patin surimi during the fermentation process with salt concentrations, namely 5%, 10% and 15%. The pH value of fermented cultivated patin surimi with a salt concentration of 5% ranges from 6.51 – 5.62, at a salt concentration of 10% ranges from 6.42 – 5.83. Meanwhile, the pH of fermented cultivated patin surimi with a salt concentration of 15% ranges from 6.42 – 6.05 (Figure 5).

3.6 Total Titrated Acid

The total titrated acid in fermented cultivated patin surimi with a salt concentration of 5% ranges from 0.15 - 0.56%, the 10% salt concentration ranges from 0.18 - 0.52%, while the total titrated acid at a salt concentration of 15% ranges between 0.18 - 0.30% (Figure 6).

The increase in total titrated acid is greater if the salt concentration added is low, namely 5%. If the salt concentration added is higher, such as 10% and 15%, then total titrated acid increase will be smaller. This is because the higher the salt content added during fermentation, the more difficult it is for the growth of lactic acid bacteria. In this way, less lactic acid will be formed.

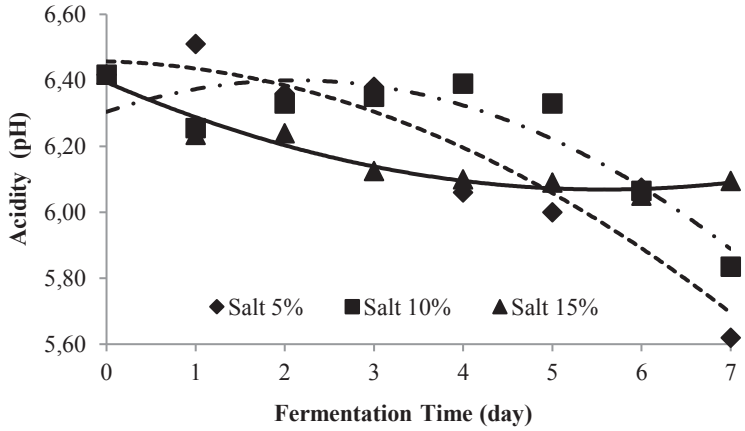

Fig. 5. Degree of acidity (pH) of fermented cultivated patin surimi for 7 days with various salt concentrations.

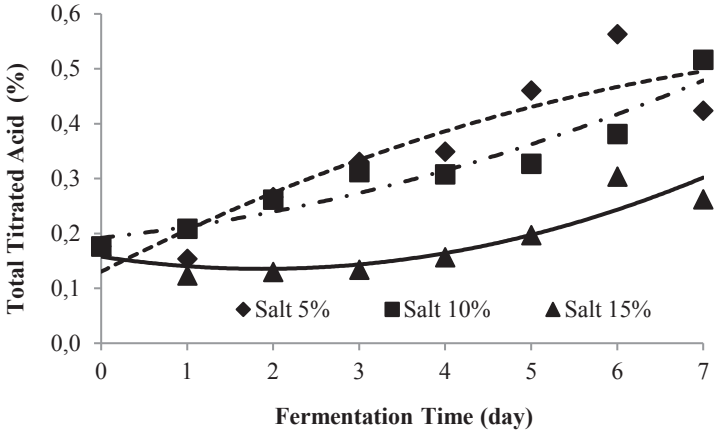

Fig. 6. Total titrated acid of fermented cultivated patin surimi for 7 days with various salt concentrations.

3.7 Salt Content

The salt content of fermented cultivated patin surimi increases with the higher concentration of added salt. Fermentation for 7 days in patin surimi with a salt concentration of 5%, 10% and 15% experienced an increase in salt content (Figure 7).

The salt content of fermented cultivated patin surimi with a salt concentration of 5% ranges from 6.85 – 9.94%, a 10% salt concentration produces a range between 8.59 – 13.43%, and a 15% salt concentration ranges from 11.47 – 14.47%. The increase in salt content during the fermentation process of cultivated patin surimi ranges from 3 to 4.5%.

3.8 Ash Content

The ash content of fermented cultivated patin surimi (Table 1) corresponds to the salt concentration added to patin surimi for fermentation. This means that the higher salt concentration added, the higher ash content of the fermented cultivated patin surimi.

Based on [2], the ash content of cultivated patin is 0.82%. The ash content of cultivated patin increased after being processed into fermented cultivated patin surimi with salt concentrations of 5%, 10%, and 15% on day 0, respectively at 3.4%, 6.99%, and 10. 72%. After fermenting for 7 days, there was a decrease in ash content in fermented cultivated patin surimi with salt concentrations of 5%, 10%, and 15%, respectively, amounting to 2.91%, 6.32%, and 9.27%.

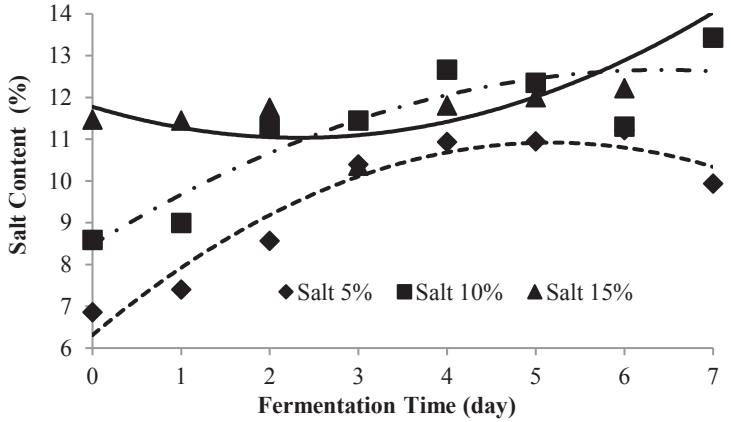

Fig. 7. Salt content of fermented cultivated patin surimi for 7 days with various salt concentrations.

Table 1. Ash content of fermented cultivated patin surimi for 7 days with various salt concentrations

Salt Concentration (%)	Ash Content (%) Days to-	
	0	7
5	3.40	2.91
10	6.99	6.32
15	10.72	9.27

4 Discussion

Different salt concentrations greatly influence the growth of lactic acid bacteria (LAB) in fermented cultivated patin surimi. According to [16] salt functions to inhibit the growth of spoilage bacteria and improve the fermentation process. Thus, with the presence of salt, there are some LAB that are tolerant and increase the fermentation process. However, if the salt concentration is high, it can inhibit the growth of lactic acid bacteria and other proteolytic microorganisms, and prevent the fermentation system from starting [17].

This is in accordance with the research results of [18] which states that the presence of more than 3% NaCl can inhibit the growth of lactic acid bacteria. Likewise, [16] stated that lactic acid bacteria, such as Lactobacillus plantarum, cannot grow at NaCl concentrations above 5%. Then [5] added that Lactobacillus plantarum isolated from tilapia fish grew well at NaCl concentrations of 2 – 7%. The salt concentration is more than 7%, namely 10% and 20%, then Lactobacillus plantarum can no longer grow.

However, there are also those who carry out fermentation using salt concentration of 10%, such as research by [4] to make tilapia fish paste and [8] to make patin meat paste. Even [19] used salt concentration of 15% to ferment seluang fish using Lactobacillus acidophilus.

LAB that can grow in fermented fish can be homofermentative proteolytic [4] and can also be amylolytic and lipolytic [5]. The types of LAB found in spontaneously fermented fish are Lactobacillus plantarum, Lacobacillus pentosus, Pediococcus pentosaceus [3, 4, 18], and Lactabacillus brevis [20]. The type of LAB affects the characteristics of spontaneously fermented fish.

The moisture content of fermented cultivated patin surimi during 7 days of fermentation decreased. This phenomenon of decreasing moisture content is the same as research [21] on anchovy rusip during fermentation. Likewise, research [22] experienced a decrease in the moisture content of bakasang cakalang during the fermentation process using salt levels of 10, 20, and 30%.

Different concentrations of salt added to fermented cultivated patin surimi affect the moisture content of fermented cultivated patin surimi. This is in line with research [21] on anchovy rusip. The moisture content of fly anchovy rusip was fermented for 12 days with salt concentration of 10% ranging from 71 - 74%, rusip with salt concentration of 15% ranging between 70 - 72%, and rusip with salt concentration of 20% ranging from 61 - 68%. The salt added to the fish meat during fermentation causes the salt to be absorbed by the fish meat. At the same time, the water molecules in the fish meat are pulled out of the fish meat, so that the moisture content of the fermented fish meat will decrease more quickly with the higher the salt concentration [6]. Water will be released into water vapor during the fermentation process.

The range of moisture content of fermented cultivated patin surimi with various salt concentrations ranges from 57.21 – 43.25%. This moisture content is smaller than that of seluang fish with salt concentration of 15% which ranges from 65 - 69% [19], African catfish with salt concentration of 10% which ranges between 72.14 - 74.81% [23] and anchovy rusip with salt concentrations ranging from 61 to 74% [21]. The low moisture content of fermented cultivated patin surimi is due to the ratio between patin surimi and roasted rice being 1 : 2. This means that the amount of patin surimi is less than the roasted rice. Even though the moisture content of patin surimi is 84 to 86% [2].

The fat content of fermented cultivated patin surimi increases with the longer the fermentation and the greater the concentration of salt added. According to [6] in general, fermented fish meat experiences lipolysis and lipid oxidation, resulting in lipid degradation. However, this lipid degradation depends on the type of fish, fermentation conditions, and additional ingredients at the time of fermentation. Because the Shidol fish type experiences an increase in lipids after fermentation. Likewise, fermented cultivated patin surimi with a salt concentration of 10% and 15% experienced an increase in fat content during 7 days of fermentation.

This increase in fat levels is due to environmental conditions for living microorganisms, such as lactic acid bacteria, which are full of pressure due to high salt levels. According to [23-25] if a microorganism experiences pressure from the environment, the microorganism adapts to its environment by biosynthesising triacylglycerol and triacylglycerol accumulates in microorganisms, namely lactic acid bacteria. If you look at Figure 3, the fat content begins to increase on the 4th or 5th day. This is related to the growth of lactic acid bacteria for salt concentrations of 10% and 15% which increased after the 4th or 5th day (Figure 1) because they had adapted to the high salt environment.

The protein content of fermented cultivated patin surimi increased during the fermentation process. The longer the fermentation process in patin surimi, the greater the amount of nitrogenous compounds. This is due to proteolytic enzymes becoming increasingly active. Proteolytic enzymes break down proteins into peptides and amino acids [3]. The shorter the nitrogen chain, the easier it is to evaporate into ammonia. Therefore, on the 7th day of fermentation, the protein content decreases and in conditions like this, it is easier for spoilage microorganisms to live.

The pH value in food processing plays a very important role in determining the shelf life of a food. The degree of acidity greatly influences the number of microorganisms that can grow, microbial cells, and product formation during the fermentation process. According to [19], pH is the concentration of hydrogen ions contained in the solution.

According to [19], the decrease in pH value is the result of an increase in the activity of lactic acid bacteria (LAB) that grow in fermented fish. Likewise, according to [8], whole patin with the addition of 10% salt and fermented for 10 days has a pH value of 5.5. The decrease in pH value is caused by the metabolism of carbohydrates originating from roasted rice and surimi from cultivated patin itself [27] into lactic acid.

The increase in total titrated acid resulted from the activity of lactic acid bacteria which metabolize carbohydrates (roasted rice) and other carbohydrate parts contained in cultivated patin surimi into lactic acid. The increase in lactic acid also occurred during fermentation of tuna viscera for 7 days [3]. Likewise, when fermenting anchovy rusip for 12 days, there was an increase in the total titrated acid [21].

The salt content of fermented cultivated patin surimi increases with the higher concentration of added salt. The increase in salt content with longer fermentation also results in fermentation of tuna viscera. The initial salt concentrations were 10%, 17.5%, and 25%. After fermentation for 7 days, the salt content of tuna viscera was 19.2%, 29.76% and 31.39% [3]. The same thing also happened in the fermentation of anchovy rusip for 12 days, so the anchovy rusip experienced an increase in salt content [21]. Likewise, what happens when fermenting sardines is that the salt content of sardines increases up to 90 days of fermentation. According to [21], the salt content increases by around 3 – 4.5% during the fermentation process because the salt seeps more and more into the fish flesh and makes it easier to lose water from the fish flesh.

The decrease in ash content during the surimi fermentation process of cultivated patin can be caused by minerals used as enzyme cofactors for biosynthesis, such as Fe, which is used for cellular processes [28]. Apart from that, Zn and Cu minerals also decreased during the fish fermentation process [6].

5 Conclusion

Lactic acid bacteria can grow spontaneously quickly at a salt concentration of 5% from day 4 to day 7, whereas at salt concentrations of 10% or 15% the growth of lactic acid bacteria is very slow in fermented cultivated patin surimi. Protein content, fat content, total of titrated acid, and salt content increased during the fermentation process. Moisture content, ash content and pH decrease during the fermentation process.The best fermentation of cultivated patin fish surimi is with a salt concentration of 5% and a fermentation time of 5 days.

The continuation of this research is to carry out an analysis of the type and amount of amino acids produced, the type and amount of fatty acids produced, and protein digestibility. Apart from that, it produces healthy food based on fermented cultivated patin surimi.

References

1. KKP. Data volume produksi perikanan budidaya pembesaran komoditas lele per provinsi. Kementeri. Kelaut. dan Perikan. 2024).
2. R Hustiany. Karakteristik produk olahan kerupuk dan surimi dari daging ikan patin (Pangasius sutchi) hasil budidaya sebagai sumber protein hewani. Media Gizi Kel. **29,** 66–74 (2005).
3. JR Besas, EI Dizon. Influence of salt concentration on histamine formation in fermented tuna viscera (Dayok). Food Nutr Sci. **03**, 201–206 (2012).
4. PR Wikandari, S Suparmo, Y Marsono, ES Rahayu. Karakterisasi bakteri asam laktat proteolitik pada bekasam. J Natur Indones. **14**, 120 (2012).

5. A Nurnaafi, I Setyaningsih, D -. Probiotic potential of bekasam lactic acid bacteria of tilapia fish. J Teknol dan Ind Pangan. **26**, 109–114 (2015).
6. SXY Chan, N Fitri, NS Mio Asni, NH Sayuti, UK Azlan, WSM Qadi, EAD Dawoud, N Kamal, MN Sarian, MA Mohd Lazaldin, CF Low, S. Harun, HS Hamezah, ER Rohani, A Mediani. A comprehensive review with future insights on the processing and safety of fermented fish and the associated changes. Foods. **12**, 558 (2023).
7. L Belleggia, A Osimani. Fermented fish and fermented fish-based products, an ever-growing source of microbial diversity: A literature review. Food Res Int. **172**, (2023).
8. BN Arfianty, S Farisi, CN Ekowati. Dinamika populasi bakteri dan total asam pada fermentasi bekasam ikan patin (Pangasius hypopthalmus). J Ilm Biol Eksperimen dan Keanekaragaman Hayati. **4**, 43–49 (2017).
9. X Zeng, W Xia, Q Jiang, F Yang. Chemical and microbial properties of Chinese traditional low-salt fermented whole fish product Suan yu. Food Control [Internet]. **30**, 590–595 (2013).
10. Association of Official Analytical Chemists. AOAC Official Method 950.01. Water (Total) in Fertilizers. Assoc Off Anal Chem. (AOAC International, Maryland, 2012).
11. Association of Official Analytical Chemists. AOAC Official Method 2003.06. Crude Fat in Feeds, Cereal Grains, and Forages.Randall/Soxhlet/Diethylether Submersion Method. Assoc Off Anal Chem. (AOAC International, Maryland, 2012).
12. Association of Official Analytical Chemists. AOAC Official Method 955.04. Nitrogen (Total) in Fertilizers. Kjeldahl Method. Assoc Off Anal Chem. (AOAC International, Maryland, 2012).
13. S Ranggana. Handbook of analysis and quality control for fruits and vegetables. (New Delhi, Tata Mc. Graw Hill Publishing Company Limited. New Delhi, 1986).
14. Association of Official Analytical Chemists. AOAC Official Method 955.03 . Ash (Acid-Insoluble) of Fertilizers. Assoc Off Anal Chem. (AOAC International, Maryland, 2012).
15. M Sezey, P Adun. Validation of mohr's titration method to determine salt in olive and olive brine. J Turkish Chem Soc Sect A Chem. **6**, 329–334 (2019). doi: 10.18596/jotcsa.496563.
16. K Waty, E Purwijantiningsih, S Pranata. Kualitas fermentasi spontan wadi ikan patin (Pangasius Sp.) dengan variasi konsentrasi garam. Biota J Ilm Ilmu-Ilmu Hayati. **4,** 24–32 (2019).
17. Y Cai, S Ohmomo, M Ogawa, S Kumai. Effect of NaCl-tolerant lactic acid bacteria and NaCl on the fermentation characteristics and aerobic stability of silage. J Appl Microbiol. **83**, 307–313 (1997).
18. W Thongsomboon, A Bunyatratchata, T Vongkampang, R Nammatra, C Prakitchaiwattana, S Siriamornpun. Dynamic changes in Thai-style fermented fish: Low-salt, short fermentation with autochthonous starter culture. Lwt [Internet]. **188**, 115427 (2023).
19. H Korkeala, T Alanko, T Tiusanen. Effect of sodium nitrite and sodium chloride on growth of lactic acid bacteria. Acta Vet Scand. **33,** 27–32 (1992).
20. S Lestari, R Rinto, SB Huriyah. Peningkatan sifat fungsional bekasam menggunakan starter Lactobacillus acidophilus. J Pengolah Has Perikan Indones. **21**, 179–187 (2018).
21. C Vichasilp, M Sangjindavong, P Wilaipun. The use of selected lactic acid bacteria isolates for acceleration of fermented fish (Pla-ra) process. Kasetsart Univ Fish Res Bull. **32**, 17–25 (2008).
22. A Kusmarwati, E Sri Heruwati, T Utami, ES Rahayu. Pengaruh penambahan Pediococcus Acidilactici F-11 sebagai kultur starter terhadap kualitas rusip teri (Stolephorus Sp.). J Pascapanen dan Bioteknol Kelaut dan Perikan. **6**, 13 (2011).

23. F Fatimah, JJ Pelealu, S Gugule, H V. Yempormase, TE Tallei. Quality evaluation of bakasang processed with variation of salt concentration, temperature and fermentation time. Pakistan J Biol Sci. **20**, 543–551 (2017).
24. A Kalista, A Supriadi, SH Rachmawati. Bekasam ikan lele dumbo (Clarias gariepinus) dengan penggunaan sumber karbohidrat yang berbeda. Fishtech. **1**, 102–110 (2012).
25. AE Angkawijaya, VC Nguyen, Y Nakamura. Lysophosphatidic Acid Acyltransferases 4 and 5 are involved in glycerolipid metabolism and nitrogen starvation response in Arabidopsis. New Phytol. **224**, 336–351 (2019).
26. HG Lee, ME Park, BY Park, HU Kim, PJ Seo. The Arabidopsis MYB96 transcription factor mediates ABA-dependent triacylglycerol accumulation in vegetative tissues under drought stress conditions. Plants. **8**, (2019).
27. J Lu, Y Xu, J Wang, SD Singer, G Chen. The role of triacylglycerol in plant stress response. Plants. (MDPI AG, 2020).
28. R Sharma, P Garg, P Kumar, SK Bhatia, S Kulshrestha. Microbial fermentation and its role in quality improvement of fermented foods. Fermentation. **6**, 1–20 (2020).
29. T. Kobayashi, T Nozoye, NK. Nishizawa. Iron transport and its regulation in plants. Free Radic Biol Med. **33**, 11–20 (2019).