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THE USE OF CASSAVA PEEL AND VINEGAR FERMENTATION SOLUTION ON THE SHELF LIFE OF RED TILAPIA FILET BASED ON THE NUMBER OF MICROBES AT LOW TEMPERATURE STORAGE

Penggunaan Larutan Fermentasi Kulit Singkong dan Cuka Terhadap Masa Simpan Filet Nila Merah Berdasarkan Jumlah Mikroba pada Penyimpanan Suhu Rendah

Annisa Nur Maharani*, Evi Liviawaty, Ayi Yustiati, Rusky Intan Pratama

Fisheries Study Program, Padjadjaran University

Bandung Sumedang Highway KM.21, Jatinangor District, Sumedang Regency, West Java 45363.

*Coresponding author: annisa20018@mail.unpad.ac.id

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ABSTRACT

Tilapia filet is a fishery product that is widely favored because of its high protein content and ease of processing. However, this product has a relatively short shelf life, so natural preservation efforts are needed to extend its shelf life. This study aims to determine the optimal concentration of vinegar in the fermentation process of cassava peels to extend the shelf life of red tilapia fillets based on the number of bacteria during low-temperature storage. This research was carried out at the Fisheries Product Processing Laboratory, Biotechnology Laboratory, Aquaculture Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University in February 2024. This study was carried out by soaking red tilapia fillets using a fermented solution of cassava peel with different vinegar concentrations, consisting of 5 treatments, namely 0%, 0.5%, 1%, 1.5%, 2% and stored at low temperatures (5^0-10^0 C). The parameters observed were the number of bacterial colonies, and the degree of acidity (pH). The concentration of 0% observation was carried out on the 1st, 3rd, 6th, 7th, 8th, 9th day while the concentration of 0.5%, 1%, 1.5%, 2% was observed on the 1st, 4th, 7th, 8th, 9th, 10th, 11th, 12th and 13th days. Based on the results of the research that has been conducted, it can be concluded that a fermented solution of cassava peel with a vinegar concentration of 1% is the best to prolong red tilapia fillets based on the number of microbes and pH. The addition of 1% cassava peel fermentation solution can maintain the freshness of the fish until the 12th day with a total number of microbes of 3.3 x 10^7 with a pH value of 6.70.

Keywords: vinegar, filet, cassava skin, storage time, microbes

ABSTRAK

Filet ikan nila merupakan produk perikanan yang banyak digemari karena kandungan proteinnya yang tinggi serta kemudahan dalam pengolahan. Namun, produk ini memiliki masa simpan yang relatif singkat, sehingga diperlukan upaya pengawetan alami untuk

memperpanjang daya simpannya. Penelitian ini bertujuan untuk menentukan konsentrasi cuka optimum pada laruran fermentasi kulit singkong untuk memperpanjang masa simpan filet nila merah berdasarkan jumlah bakteri selama penyimpanan suhu rendah. Penelitian ini dilaksanakan di L aboratorium Pengolahan Hasil Perikanan, Laboratorium Bioteknologi, Laboratorium Akuakultur, Fakultas Perikanan dan Ilmu Kelautan, Universitas Padjadjaran pada bulan Februari 2024. Penelitian ini dilakukan dengan merendam filet nila merah menggunakan larutan fermentasi kulit singkong dengan konsentrasi cuka yang berbeda, terdiri dari 5 perlakuan yaitu 0%, 0,5%, 1%, 1,5%, 2% dan disimpan dalam suhu rendah (5^0-10^0 C). Parameter yang diamati adalah jumlah koloni bakteri, dan derajat keasaman (pH). Konsentrasi 0% pengamatan dilakukan pada hari ke-1, 3, 6, 7, 8, 9 sedangkan untuk konsentrasi 0,5%, 1%, 1,5%, 2% dilakukan pengamatan pada hari ke-1, 4, 7, 8, 9, 10, 11, 12 dan 13. Berdasarkan hasil penelitian yang telah dilakukan, maka dapat disimpulkan bahwa larutan fermentasi kulit singkong dengan konsentrasi cuka 1% adalah yang terbaik untuk memperpanjang filet nila merah berdasarkan jumlah mikroba dan pH. Penambahan larutan fermentasi kulit singkong 1 % dapat mempertahankan mutu kesegaran ikan hingga hari ke-12 dengan total jumlah mikroba $3{,}3 \times 10^7$ dengan nilai pH 6,70.

Kata Kunci: cuka, filet, kulit singkong, masa simpan, mikroba

INTRODUCTION

Tilapia is a widely cultivated commodity throughout Indonesia. According to the Ministry of Maritime Affairs and Fisheries (2020), tilapia production reached 1.17 million tons in 2020 and increased to 1.30 million tons the following year. Tilapia is generally sold and served live and whole or as fillets. Red tilapia is one raw material that can be used for fillets. Fish fillets have high water, fat, and protein content, making them highly susceptible to spoilage (Litaay et al., 2018). Ready-to-cook foods are susceptible to contamination and deterioration, which can occur physically, chemically, and biologically. Addressing the challenges faced by fillet products has led to efforts to extend the shelf life of tilapia fillets.

One effort that can be taken to maintain the freshness of red tilapia fillets is a low-temperature preservation method. The use of low temperatures (50-100°C) is a safe and inexpensive preservation method (Santoso et al., 2017). In addition to utilizing low-temperature storage, the shelf life of tilapia fillets can also be extended by using various types of preservatives, including those containing microorganisms that produce antibacterial compounds.

Lactic acid bacteria (LAB) are known as biopreservatives capable of producing metabolites that suppress the growth of bacteria that cause spoilage, thereby extending the shelf life of food. LAB produce antibacterial compounds such as lactic acid, acetic acid, diacetyl, hydrogen peroxide, and bacteriocins (Ravindran et al. 2016). Lactic acid bacteria can be obtained from the fermentation process of organic materials. Commonly used materials include glucose, molasses, corn, potatoes, and cassava (Bomrungnok et al., 2012).

Agro-industrial waste, such as cassava peels, still contains nutrients that can be used as a growth medium for microbes. Lactic acid is generally produced through the fermentation of materials high in glucose and carbohydrates by lactic acid bacteria (Rahman et al., 2013). This is in line with Turyoni's (2005) statement that cassava peel contains 4.55% carbohydrate, making it a potential energy source for microorganisms in the fermentation process. The addition of acidic compounds to organic waste media can lower the acidity (pH), creating a favorable environment for lactic acid bacteria (LAB), but less favorable for spoilage microbes (Samsuri et al., 2007). The public is generally more familiar with acetic acid (vinegar) than other organic acids.

Based on the explanation above, a study was conducted using a fermented cassava peel solution with added vinegar concentrations as a natural preservative for red tilapia fillets. The aspects analyzed in this study included the total microbial count (TPC) and the acidity (pH). The total bacterial count provides an indication of the extent to which the bacteria in the tilapia fillets meet established standards. The maximum standard for bacterial counts in fillets is 106 cfu/g (SNI 2696:2020). The pH value of tilapia fillets is an indicator for determining their quality (Silvia et al., 2022). Using these parameters, conclusions can be drawn regarding the maximum shelf life and optimum vinegar concentration of the cassava peel fermentation solution.

RESEARCH METHODS

This research was conducted in February 2024. Fermentation solution preparation, tilapia filleting, and storage were conducted at the Fisheries Product Processing Technology Laboratory. Microbial and pH testing were conducted at the Biotechnology Laboratory, and fish acclimatization was conducted at the Aquaculture Laboratory, Faculty of Fisheries and Marine Sciences, Padjadjaran University.

The main materials used in this study were cassava peels, red tilapia, vinegar, Nutrient Agar (NA), and distilled water. The main tools used in this study were knives, cutting boards, scales, jars, measuring cups, cling wrap, hand counters, colony counters, petri dishes, Elenmeyer flasks, spatulas, test tubes, hot plates, Bunsen burners, refrigerators, pH meters, and incubators. The method used in this study was an experimental method consisting of five immersion treatments in cassava peel fermentation solutions with various vinegar concentrations: 0%, 0.5%, 1%, 1.5%, and 2% (Wali & Abed, 2019). The treatment given was soaking in a cassava peel fermentation solution with different vinegar concentrations based on the weight of the cassava peel for 30 minutes.

Preparation of Cassava Peel Fermentation Solution

The procedure for preparing cassava peel fermentation solution according to Nisah et al. (2021) which has been modified begins by cleaning the cassava peel obtained from the market using running water, then drying it. The cassava peel is cut or shredded with a thickness of 1 mm and a length of 5 cm, then weighed as much as 150 grams using a digital scale. Aquadest water is measured using a measuring cup and added to the jar at twice the height of the cassava peel in the jar. Vinegar is measured at concentrations of 0%, 0.5%, 1%, 1.5%, and 2% of the weight of the cassava peel, then dissolved in the jar containing aquadest and stirred until homogeneous. The weighed cassava peel is placed in the jar, then the jar is tightly closed and lined with plastic cling wrap. The jar is stored at room temperature (25-30°C) and fermented for 5 days before finally being filtered using a sieve for use.

Fish Handling and Filleting

Live fish were obtained from suppliers or farmers in the market and then transported to the Invertebrate Laboratory of the Faculty of Fisheries and Marine Sciences, Padjadjaran University, in plastic bags filled with water and oxygen. Upon arrival, the fish were acclimatized for 2 days in an aerated holding tank to reduce transport stress, which can affect fillet freshness (Afrianto et al., 2014). The fish were killed by immersing them in ice water for 10 minutes, then stored in an ice box for 30 minutes. Fillets were prepared in the Fishery Products Technology Laboratory in an air-conditioned room (19-23°C). According to Moeljanto (1992), filleting is done by cleaning red tilapia, then slicing the flesh from head to tail, following the ribs to maximize the meat harvested without including unwanted parts. The fillets were washed with cold water at 10°C to remove dirt and blood, then the fillets were drained.

Application of Cassava Peel Fermentation Solution on Tilapia Fillets

The procedure for applying cassava peel fermentation solution to red tilapia fillets according to Nisah et al. (2021) begins by soaking the washed and drained tilapia fillets in cassava peel fermentation solution with vinegar concentrations of 0%, 0.5%, 1%, 1.5%, and 2%, respectively, for 30 minutes. Afterward, the fillets are drained and placed on a mica plastic sheet lined with a liquid absorbent. The fillets are then wrapped in plastic wrap and placed in a refrigerator at 5–10°C for the specified testing period.

Procedure Analysis

Total Number of Bacteria

The procedure for testing the total number of bacteria using the Total Plate Count (TPC) method based on the modified National Standardization Agency (SNI 2332.3:2015) is as follows. 3 grams of fillet samples were weighed from three points, namely near the head, middle, and base of the tail, then ground in a mortar and added with 27 mL of aquadest solution to produce a dilution of 10^-1. A test tube containing 9 mL of aquadest was prepared, covered with sterile cotton, and stored on a shelf. A total of 1 mL of the 10^-1 dilution sample was put into a tube containing 9 mL of aquadest to produce a dilution of 10^-2, stirred until homogeneous, and a similar process was carried out until a dilution of 10^-6. A total of 1 mL of sample from each dilution was taken and put into a sterile petri dish, then added with 10-15 mL of NA, and done in duplicate. The petri dish was then closed and rotated in a figure eight so that the sample and NA were mixed completely. The petri dishes, ready to be packaged using brown paper, were incubated upside down at 35°C ± 1°C for 48 ± 2 hours. The number of microbial colonies was then calculated using the following equation according to the National Standardization Agency (SNI 2332.3:2015):

$$N = \frac{\Sigma C}{[(1 \times n1)+(0{,}1 \times n2)] \times d}$$

Information:

N : The number of product colonies, expressed in colonies/mL or colonies/g

ΣC : The number of colonies on all plates was counted

N1 : Number of plates in the calculated dilution

N2 : The number of plates in the second dilution was counted.

d : The first dilution calculated

Acidity Degree (pH)

The pH value of tilapia fillets was measured using a pH meter to determine chemical changes during storage. The pH measurement procedure, modified from Widiani (2011), begins by taking 3 grams of tilapia fillet meat from three points (near the head, middle, and base of the tail) and then crushing it in a mortar until smooth. The ground meat was then placed in a beaker glass containing 27 mL of distilled water and homogenized using a spatula, then filtered through a sieve. The filtered sample was measured using a pH meter that had previously been calibrated with standard buffer solutions of pH 4 and pH 7.

Data Analysis

The collected data was analyzed using a comparative descriptive method, then presented in a table to see the comparison based on pH and total number of bacteria.

RESULT

Total Number of Microbes

Red tilapia fillets soaked in cassava peel fermentation solutions with different vinegar concentrations yielded varying results in bacterial colony count tests. The microbial counts of red tilapia fillets soaked in fermentation solutions with different vinegar concentrations during low-temperature storage are shown in table1.

Table 1. Total Bacterial Count (cfu/g) of Red Tilapia Fillets Soaked in Cassava Peel Fermentation Solutions with Different Vinegar Concentrations During Low-Temperature Storage (5^0 -10^0 C).

Storage Day to -	Vinegar Concentration (%)				
	0	**0,5**	**1**	**1,5**	**2**
1	$2,9 \times 10^3$	$2,6 \times 10^3$	$2,5 \times 10^3$	$2,5 \times 10^3$	$3,0 \times 10^3$
3	$1,6 \times 10^4$	-	-	-	-
4	-	$3,4 \times 10^4$	$2,8 \times 10^4$	$3,0 \times 10^4$	$3,0 \times 10^4$
6	$1,4 \times 10^5$	-	-	-	-
7	$3,1 \times 10^6$	$2,1 \times 10^6$	$1,2 \times 10^6$	$1,6 \times 10^6$	$1,6 \times 10^6$
8	**$7,8 \times 10^6$**	$2,2 \times 10^6$	$1,6 \times 10^6$	$1,7 \times 10^6$	$2,0 \times 10^6$
9	$2,4 \times 10^7$	**$2,7 \times 10^6$**	$1,7 \times 10^6$	$2,7 \times 10^6$	**$2,6 \times 10^6$**
10	*	$1,6 \times 10^7$	$2,8 \times 10^6$	**$6,5 \times 10^6$**	$1,5 \times 10^7$
11	*	$1,9 \times 10^8$	**$3,2 \times 10^6$**	$2,1 \times 10^7$	$2,8 \times 10^7$
12	*	$3,4 \times 10^8$	$3,3 \times 10^7$	$2,2 \times 10^8$	$2,9 \times 10^8$
13	*	$4,0 \times 10^8$	$1,9 \times 10^8$	$3,5 \times 10^8$	$3,8 \times 10^8$

Information :
- = no TPC testing was performed
* = TPC testing was not performed because the total microbial count had reached the rejection limit the previous day.

The results of the study showed that red tilapia fillets treated with cassava fermentation solution with a vinegar concentration of 0% had a shelf life of up to the 8th day with a total number of bacteria of $7.8x10^6$. A vinegar concentration of 0.5% had a shelf life of up to the 9th day with a total number of bacteria of $2.7x10^{6.}$ A concentration of 1% provided a shelf life of up to the 11th day with a microbial count of $3.2x10^6$. A vinegar concentration of 1.5% had a consumption limit of up to the 10th day with a total number of bacteria of $6.5x10^6$. A vinegar concentration of 2% was still suitable for consumption until the 9th day with a total number of bacteria of $2.6x10^6$. The maximum number of bacterial colonies that were safe for consumption was 106 cfu/g (Connell 1990; SNI 2696:2020). The acceptance limit for fillets, apart from the number of bacteria, is also supported by the fact that the neutral, distinctive fish aroma is still present, and there is no distinct smell of rotten fish in all treatments.

Acidity Degree (pH)

The pH value is an important parameter that determines the acidity level of red tilapia fillets, which can then be used as a measure of the freshness of the fish. The pH values of red tilapia fillets soaked in cassava peel fermentation solutions and different vinegar concentrations during cold storage are presented in Table 2.

Table 2. Acidity Level (pH) of Red Tilapia Fillets Immersed in Cassava Peel Fermentation Solutions with Different Vinegar Concentrations During Low Temperature Storage (5^0 -10^0 C).

Day to -	Vinegar Concentration in Cassava Peel Fermentation Solution (%)				
	0	**0,5**	**1**	**1,5**	**2**
1	6,25	6,20	6,00	5,90	5,85
3	6,0	-	-	-	-
4	-	5,85	5,80	5,80	5,80
6	6,10	-	-	-	-
7	6,40	5,90	5,90	5,90	5,95
8	**6,55**	6,10	6,00	6,10	6,20
9	7,00	**6,55**	6,25	6,25	6,45
10	-	6,80	6,30	6,55	**6,70**
11	-	6,90	6,50	**6,70**	6,80
12	-	7,00	**6,70**	6,80	6,90
13	-	7,30	7,00	7,10	7,20

Information:
- = no pH measurements were performed

Red tilapia fillets have a pH acceptance limit of 6.70 in accordance with several studies that have been carried out that the pH value of red tilapia fillets without preservation treatment and stored at low temperatures has an acceptance limit until the 7th day with a pH value of 6.70 (Wanabhakti 2011; Lestary 2011). The pH value of red tilapia fillet with 0% vinegar concentration has a shelf life of up to 8 days with a pH value of 6.55. Red tilapia filets treated with soaking in fermented cassava peel solution with the addition of 0.5% vinegar have a shelf life of up to 9 days with a pH value of 6.55. A vinegar concentration of 1% has the same shelf life up to the 12th day with a pH value of 6.70. Red tilapia fillets that were treated by soaking in a fermented cassava skin solution with the addition of 1.5% vinegar had a shelf life of up to the 11th day with a pH value of 6.70 and red tilapia fillets that were treated by soaking in a fermented cassava skin solution with the addition of 2% vinegar had a shelf life of up to the 10th day with a pH value of 6.70.

Data Recapitulation

Based on observations, changes in pH values in red tilapia fillets during storage showed an increasing trend over time. To provide a comprehensive overview of quality dynamics during storage, a summary of pH values and bacterial counts for each treatment is presented in Table 3.

Table 3. Tabulation of Red Tilapia Fillet Data Based on Cassava Peel Fermentation Solution Immersion Treatments with Different Vinegar Concentrations During Low-Temperature Storage.

No.	Observation	Vinegar Concentration in Cassava Peel Fermentation Solution (%)				
		0	**0,5**	**1**	**1,5**	**2**
1	The number of bacteria at the acceptance limit is 106 cfu/g according to Connell (1990)	$7,8 \times 10^6$	$2,7 \times 10^6$	**$3,2 \times 10^6$**	$6,5 \times 10^6$	$2,6 \times 10^6$
2	Shelf Life Based on Number of Bacteria (Days to-)	8	9	**11**	10	9
3	Acidity Degree (pH)	6,55	6,55	**6,5**	6,55	6,45
4	Degree of Acidity (pH) Acceptance Limit	6,55	6,55	**6,70**	6,70	6,70
5	Shelf Life Based on pH value (Day to-)	8	9	**12**	11	10
6	Number of Bacteria Based on pH Acceptance	$7,8 \times 10^6$	$2,7 \times 10^6$	**$3,3 \times 10^7$**	$2,1 \times 10^7$	$1,5 \times 10^7$

DISCUSSION

Total Number of Microbes

The high microbial counts in each treatment do not necessarily indicate that the treatment is unfit for consumption, as the microbes growing are lactic acid bacteria, not pathogens. The acidity analysis (Table 2) indicates a tendency toward an acidic pH.

The differences in shelf life between treatments are due to the different vinegar concentrations used. A 1% vinegar concentration had the lowest bacterial growth compared to the other treatments, resulting in the longest shelf life, up to 11 days, based on a bacterial colony count of 106 (Connell, 1990). Increasing the vinegar concentration did not result in a decrease in bacterial counts, as evidenced by the addition of a 2% vinegar concentration, which had a shorter shelf life than the addition of 1% and 1.5% vinegar. Leesmith, (2005) also reported that the use of 1% acetic acid can inhibit the growth of Bacillus sp., E. coli, L. monocytogenes, and S. aureus.

Red tilapia fillets soaked in a fermentation solution with vinegar (0%, 0.5%, 1%, 1.5%, and 2%) had a shelf life of 1-4 days longer than unpreserved red tilapia fillets stored at low temperatures, which had a shelf life of up to 7 days (Lestary, 2011; Wanabhakti, 2011; Aftianto & Liviawaty, 2010). This means that the addition of vinegar to the fermented cassava peel solution successfully extended the shelf life of red tilapia fillets. LAB are active in an acidic pH environment, continuously producing lactic acid and other antimicrobial compounds, preventing the optimal growth of pathogenic bacteria. Vinegar is used as a fermentation control agent because its acidic properties can lower the pH, creating a more optimal environment for the growth of lactic acid bacteria.

The acetic acid content in vinegar, in addition to its function as an environmental control agent, is also used as an antimicrobial. Acetic acid is known as an antimicrobial that can inhibit

pathogenic bacteria. Acetic acid is used in conjunction with other antimicrobial compounds, synergistically increasing their effectiveness in inhibiting the growth of microorganisms. Acetic acid, as a preservative, possesses antimicrobial properties because it contains an undissociated fraction that can enter microbial cells (Doesburg, 2006). Furthermore, its lipophilic nature facilitates penetration of cell membranes, which are largely composed of phospholipids and lipids (Ray, 2004). Once inside the cell, this undissociated fraction dissociates, increasing the concentration of H+ ions and lowering the intracellular pH, thereby disrupting the cell's biological functions (Yuliana et al., 2014).

Another factor influencing low microbial growth is low temperature conditions (50-10 0C), which can suppress the growth of spoilage bacteria. Biochemical processes that occur during storage conditions at low temperatures (5-10 °C) can suppress the growth of spoilage bacteria. Biochemical activities in the fish body that cause quality decline also occur more slowly at these cold temperatures (Gelman et al., 2001). This is in line with the results of research by Erikson & Misimi (2008), who reported that enzymatic activity and bacterial growth in catfish fillets can be significantly inhibited when stored at low temperatures. Although bacterial growth can be inhibited, groups of microbes that are able to survive and be active, such as psychrophilic and psychrotrophic bacteria, so that tilapia fillets still experience the process of spoilage even though they have been packaged and stored at cold temperatures (Sopandi & Wardah, 2014). The total number of bacteria generally decreases during the cooling or freezing process, although this decrease occurs primarily in thermophilic and mesophilic bacteria (Afrianto & Liviawaty, 2010). The main microorganisms responsible for spoilage of fishery products include Pseudomonas, Achromobacter, Flavobacterium, Coryneform, and Micrococcus, which have an optimum growth temperature in the range of 5–10 °C. (Afrianto & Liviawaty 2010).

Acidity Degree (pH)

The pH values in all treatments immersed in the fermentation solution with added vinegar were lower than those in the control treatment. This was due to the presence of LAB activity in the 0.5%, 1%, 1.5%, and 2% treatments, as well as the acetic acid content in the vinegar, which caused the low pH. In general, the five treatments, with each vinegar concentration in cassava peel fermentation (0%-2%), exhibited similar pH change patterns. This pattern initially decreased from day 1 to day 4, reaching a range of 5.80-6.00, before increasing on subsequent observation days.

The decrease in pH in all treatments from day 1 to day 4 was due to ongoing glycolysis and the degradation of adenosine triphosphate, phosphoric acid, or creatine, which results in the production of a series of acidic substances (Zhang et al. 2011). During storage, the pH value of fish meat will decrease due to the activity of the enzyme glucokinase which converts glycogen into lactic acid, which increases over time and results in the accumulation of decomposition products. The accumulation of decomposed lactic acid causes the pH value to decrease (Asni et al., 2022). Adenosine triphosphate (ATP) is a high-energy organic compound found in muscle or meat, and in fish it is synthesized primarily from glycogen and a small amount of creatine phosphate under anaerobic conditions (Quang 2005). The glycolysis process will continue until it produces lactic acid as the end product, which causes a decrease in the pH of the meat. This accumulation of lactic acid lowers the pH of fish muscle, suppresses microbial activity, and slows the rate of deterioration (Zakaria, 2008). A longer period of pH decline indicates a longer rigor mortis process, thus inhibiting quality decline due to bacterial activity, which ultimately can extend shelf life (Santoso et al., 2017). After the pH decreased in all treatments from day 1 to day 4, it then increased on the following observation days. The pH value will continue to increase until it exceeds 7 in all treatments on the 13th day according to the statement of Asni et al., (2022) who said the pH value will decrease to 5 and then increase

to exceed 7. The increase in pH value is caused by the activity of microorganisms. The optimum pH value for the growth of spoilage bacteria is 6.80 (Parija, 2012). Based on this description, the best characteristics for the pH parameter are fillets that experience the lowest and longest pH decrease to reach pH 6.80, which is the optimum pH for the growth of spoilage bacteria. The lowest and longest pH decrease to reach 6.80 occurred in red tilapia fillets from the vinegar addition concentration level 1%.

Microorganisms tend to accelerate protein degradation, causing the accumulation of nitrogen-containing base compounds such as ammonia and biogenic amines, which further increase the pH of the sample (Zhou et al. 2011). The turning point of pH changes can reflect the level of microbial action in fish fillets, which indicates the initial time of fillet spoilage (An et al. 2023). The decline in the quality of red tilapia fillets is indicated by an increase in pH values followed by different aroma changes in each treatment after passing the acceptance limit day due to the increasing amount of ammonia, according to Dangur et al. (2020), stating that the bacterial metabolic process causes the production of ammonia (NH3), which is the main cause of the rotten odor in meat.

Data Recapitulation

The limit of bacterial count acceptance according to Connell, (1990) with the number of bacteria 106 is the last acceptable limit for food ingredients that are safe for consumption, but the high growth of bacteria is closely related to the value of the degree of acidity. The results of the study showed that the limit of bacterial acceptance according to Connell, (1990) still had a low pH value in all treatments, namely 6.45-6.55 so that it was suspected that the bacteria that grew and dominated were still lactic acid bacteria, in accordance with research conducted by Martin, (2010) regarding the soaking of red tilapia fillets soaked in mixed culture media of LAB L. bulgaricus and S. thermopilus which stated that red tilapia fillets at the acceptance limit on the 9th day (106) could not be concluded as unfit for consumption because the microbes that grew were lactic acid bacteria and not pathogenic bacteria because the results of the pH value were still low and in the range of values that were still suitable for lactic acid bacteria. Budiyanto & Agus, (2004) stated that the activity of lactic acid bacteria Lactobacillus and Acetobacter occurs in the pH range of 5.8-6.6.

The degree of acidity can be used as an indicator of the freshness of red tilapia fillets because changes in pH reflect microbial activity and biochemical processes that occur during storage. Fresh red tilapia fillets have a slightly acidic pH of 6.4-6.6, consistent with several studies showing that the pH of fresh fish is between 6.4 and 6.6, or close to the neutral pH of 7.0 (Fadhli et al., 2022; Nurqaderianie et al., 2016; Sulistijowati et al., 2020). Research conducted by Lestary, (2011) stated that the acceptable limit for red tilapia fillets without preservative treatment and stored only at low temperatures has a shelf life of up to 7 days with a pH of 6.7. A pH value exceeding 6.7 is the optimum pH condition for the growth of spoilage bacteria such as salmonella, which thrives at a pH of 6.8 (Parija, 2012). Therefore, the pH value is used as a benchmark for determining the shelf life of red tilapia fillets, with an acceptable pH of 6.7.

Based on this description, red tilapia fillets soaked in cassava peel fermentation solution with a 0% vinegar concentration have a shelf life of up to 8 days with a pH of 6.50 and a bacterial colony count of 7.8×10^6. A 0.5% vinegar concentration has a shelf life of up to 9 days with a pH of 6.55 and a bacterial colony count of 2.7×10^6. A 1% vinegar concentration has a shelf life of up to 12 days with a pH of 6.70 and a bacterial colony count of 3.3×10^7. A 1.5% vinegar concentration has a shelf life of up to 11 days with a pH of 6.70 and a bacterial colony count of 2.1×10^7. A 2% vinegar concentration has a shelf life of up to 10 days with a pH of 6.70 and a bacterial colony count of 1.5×10^7. These acceptable limits are also supported

by the presence of a neutral aroma and no foul odor in all treatments. Aroma can be used as an indicator of fish freshness (Lestari, 2015).

The process of quality deterioration and decay continues even though the red tilapia fillets have been stored at low temperatures and soaked in a cassava peel fermentation solution with the addition of different vinegars that can produce lactic acid bacteria (LAB). Changes that occur in red tilapia fillets during storage are caused by enzymes and spoilage bacteria that begin to break down proteins into peptides and amino acids. Furthermore, through the deamination process, amino acids are converted into ammonia and amines (Gram & Dalgaard 2002).

CONCLUSION

Based on the results of the research that has been conducted, it can be concluded that the cassava peel fermentation solution with a vinegar concentration of 1% is the best concentration to extend the shelf life of red tilapia fillets based on the number of microbes and pH. The addition of 1% cassava peel fermentation solution can maintain the quality of fish freshness until the 12th day with a total number of microbes of 3.3 ´ 107 with a pH value of 6.70.

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