Optimization of Skipjack Tuna *(Katsuwonus Pelamis)* Quality Factors in Chilled Box Storage Using Taguchi Method

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Abstract

Skipjack tuna (Katsuwonus pelamis) is one of tuna fish species in Indonesia,which is perishable and must be kept its freshness by chilling. Aim of this research were to optimize influenced quality factors and to find the best method for reduce deterioration process. The research was conducted by using Taguchi Method, which was used quality robustness concept and multi-performance characteristics to achieve optimal combination of factors. Controlled factors during chilled storage were; weight ratio of ice and fish (A), box size (B), time replacing ice (C), ice form (D), concentration of added salt (E), fish form (F) and number of fishes per kg (G). Quality responses for assessing the freshness were; peroxide value (POV), water content (WC), pH value, texture and Total Plate Count (TPC). The result showed, increase of peroxide value was affected by A of 26.52% and C of 26.52%. Increase of water content was influenced by F of 37.25%. Fluctuation of pH was affected by G of 59.58%. Decrease of texture was influenced by A of 40.47%. Increase of TPC was influenced by A of 31.20%. Priority Scale of factors during storage were A, E, D, G, F, B, and C. Result of analysis muli-performance characteristics gave a conclusion that factors A1, B1, C1, D2, E2, F2 and G2 are the best chilling storage methods.

Keywords: *Multi-performance Characteristics, Skipjack Tuna, Taguchi Methode*

1. INTRODUCTION

Indonesia is an archipelago country which has long coastal line and large potential sea. This condition leads to high potency of fishery products that could be as protein sources of human life. The fishery products became one of main Indonesian export commodities. Based on data from the Central Statistics Agency (BPS) for the January-July 2021 period, Indonesia has exported 1.2 million tonnes of yellowfin tuna with a total export value of USD 4.8 million worldwide with the main markets being Japan (95.09%), the United States (1.85%), Vietnam (1.55%), Australia (0.47%), and Singapore (0.44%) (Kementerian Perdagangan, 2021).

Skipjack tuna (*Katsuwanus pelamis*) or *cakalang* fish is one most consumed fish in Yogyakarta area at southern coast of Java island, and normally it was supplied by fishermen from northern part. Main problem of these fishes in Yogyakarta was decrease of its quality especially its freshness when it arrived at end consumers. Distance from northern to southern part of Java island was approximately 125 km and it took 3-4 hours.

Fish belonged to most perishable products, because it contained high protein which was potential to be degraded by microbial activities. When the fish was captured and died, it was weaker and easier to be attacked by microbes which led to deterioration process. Some external factors could accelerate the deterioration process such as temperature, physical impacts, bad post-fishing handling etc. (Chakma et al., 2020)

One of the characteristics of fish products are perishable, or easily damaged. The causes of this is due to the quality and microbial enzymatic activities are still going after the fish dies. If the activity increases, the decline in the quality of the fish was quick. The length of the fish supply chain, will lead to enzymatic and microbial activity lasts longer, so the fish products that the consumer is in a bad state. Enzymatic and microbial activity that occurs in the body of the fish can be minimized by storage at cold temperatures (Chakma et al., 2020).

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Storage that has been done by the business of cold storage is to use ice but not optimal keeping fish remain fresh. Therefore this study conducted optimization factors that affect the quality of tuna during storage. Further factors determining priorities for maintaining product quality remains good tuna, as well as determining the best storage method tuna.

2. MATERIALS AND METHODS

The research was conducted by using Taguchi Method, which was used quality robustness concept and multi-performance characteristics to achieve optimal combination of factors to maintain the freshness. It was based on experimental design for achieving efficient characteristics of product or production process, then combined with statistical analysis for every deviation or appeared variants (Monika Kussetya Ciptani, 1999). Taguchi introduced an integrated design which is divided into three steps; a) system design, in which quality characteristics and influenced factors were determined and classified into: smaller the better, nominal the best, larger the better; b) parameter (measure) design, the parameters were focused on product or process become robust from environmental influences, c) tolerance design. Three main tools of Taguchi were Orthogonal Array, ANOVA and SN Ration (S/N) (Khosla, 2006).

The controlled factors during chilled storage were; weight ratio of ice and fish (A), box size (B), time replacing ice (C), ice form (D), concentration of added salt (E), fish form (F) and number of fishes per kg (G). The quality responses for assessing the freshness were; peroxide value (POV), water content (WC), pH value, texture and Total Plate Count (TPC).

The fresh fishes were purchased at marketing point of fishermen at Jalan Bantul in Yogyakarta. They sold the fishes normally at 02.00 – 03.00 am, because they would be distributed to markets in Yogyakarta city. For every treatment 3-5 kg fresh fishes were provided. The number of fishes in every 1 kg weight was 4 to 5 pieces. The storage boxes for experiments (Styrofoam) were provided from the store and they were usually used by fish-seller in the market and had 2 dimensions 45 x 29 x 14 cm^3 and 35 x 21 x 14 $cm^{3.}$ The household salt (NaCl) and block-ice were provided from market at Jalan Kaliurang, Sleman, Yogyakarta. The controlled factors and their levels were described in table 1. The implementation of controlled factors and their levels were systematically arranged by using Orthogonal Array in table 2 and the experiments were conduted based on the mentioned table.

Table 1. Controlled factors and levels.

Factors	Level	
	1	2
Percentage weight of ice and fish (A)	1 : 1	1.5 : 1
Experiment size (B)	45 x 29 x 14 cm^3	35 x 21 x 14 cm^3
Time for ice replacing (C)	12 hours	24 hours
Ice Form (D)	crushed ice	Cube ice
Added salt concentration (E)	5%	10%
Fish form (F)	Drawn fish	Dressed fish
Number of fishes /kg (G)	4 fishes	5 fishes

Table 2. Orthogonal Array for Conducting Research

Experiment	Factors						
	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

For example experiment IV was conducted by factors as follow: A (1:1), B (35 x 21 x 14 cm^3), C (24 hours), D (cube ice), E (10%), F (drawn fish), G (4 fishes).

3. RESULTS AND DISCUSSION

3.1 Measurements of the parameters

The decline of the quality of the resulting changes to the content of the fish. In this research, the test parameters to determine fish freshness. The parameters are the peroxide value, water content, pH, texture, and total plate count. Quality parameters are done every day for 5 days with 3 repetitions. According to the results of testing that has been done during the storage experiment VI dismissal must be made on the fourth day of storage. The combinations of experiment VI level are 1.5:1, size box (45x29x14) cm^3, 24 hour replacement time ice, ice cube, concentration of salt 5%, the shape of fish dressed fish, and 4 fish of 1 kg. Condition of VI box on the fourth day showed that a bad odor, rotten, meat texture is soft, slimy, and if done with a finger pressure feels sticky. Therefore do dismissal storage.

3.1.1. Peroxide value (POV)

Peroxide value response rate during 5 days of storage are shown in Figure 1.

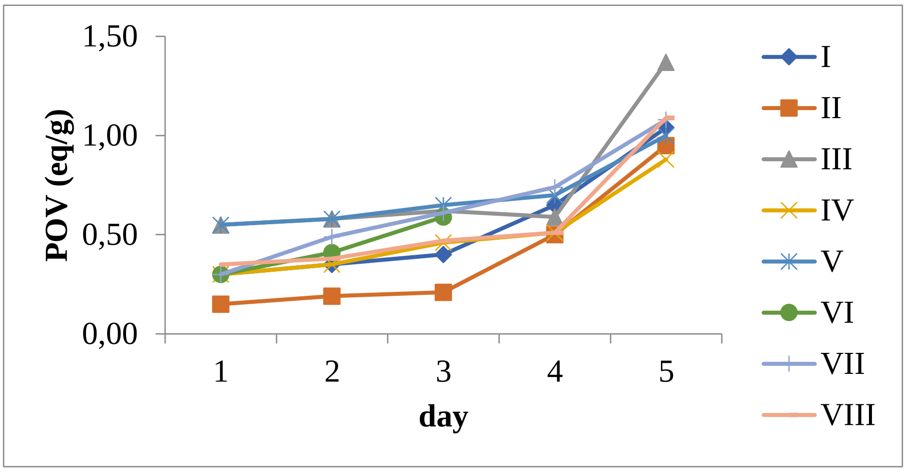

Figure 1. The peroxide response rate

In figure 1 shows that the peroxide response rate increased every day. On the fifth highest number of peroxide was 1.37 eq / g in box III. The smallest peroxide value is in box IV of 0.88 eq/g. The increasing peroxide value is supported by previous research that suggested by Sanger (2010). In the study explain that the longer the storage, the peroxide levels will increase. This is due to peroxide formed in the propagation stages with new free radicals, as well as uncontrolled temperature rise. The increasing of POV describes damage fish quality. POV is the result of fat oxidation that occurs in fish meat that is usually characterized by a rancid smell. POV are affected by fat content, temperature, oxygen, and moisture. The fat content of fish meat can affect how much POV formed.

3.1.2. Water Content

Water is an important component in food products, as well as fish products. Water content of the response values shown in figure 2.

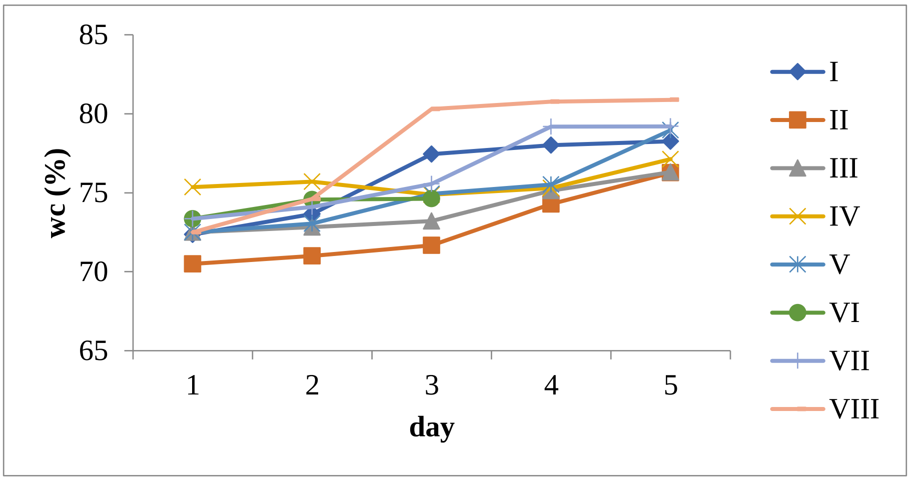

Figure 2. The water content (%)

In figure 2 showed that the water content increased from the second day to the fifth day on all box or experiment. On the first day, the lowest water content at the box II is 70.50% and the highest is box IV of 75.35%. After storage for 5 days, the highest water levels are box VIII which amounted to 80.88%. While the lowest water content at the box II by 76.26%

The increase of water content describes the deterioration in the quality of skipjack tuna. On the ice storage, the ability of the muscles to hold the water in the tissue fish gradually decreases, so water are easily dislodged in the tissue. This causes softening of fish meat. Water ice melt can enter the tissue of fish meat that has been damaged. So, the water content in fish has increased each day. According to Sayekti (2011), an increasing water content can be affected by environmental humidity. Low humidity will accelerate the decline of water content that due to evaporation of water (dehydration). While high humidity slows evaporation rate, but when followed by high temperatures will encourage the growth of bacteria and fungi. Therefore, high humidity and low temperatures are ideal conditions for the storage of skipjack tuna.

3.1.3. pH

The next fish quality parameters are pH, or acidity. PH numbers range is 0-14. If pH indicate 7, then the solution is called to be neutral. However, if the pH showed less than 7, it is acid. If the pH is more than 7, said base. pH neutral is safe for food, or between 6.5 to 7.5. PH value response can be shown in Figure 3.

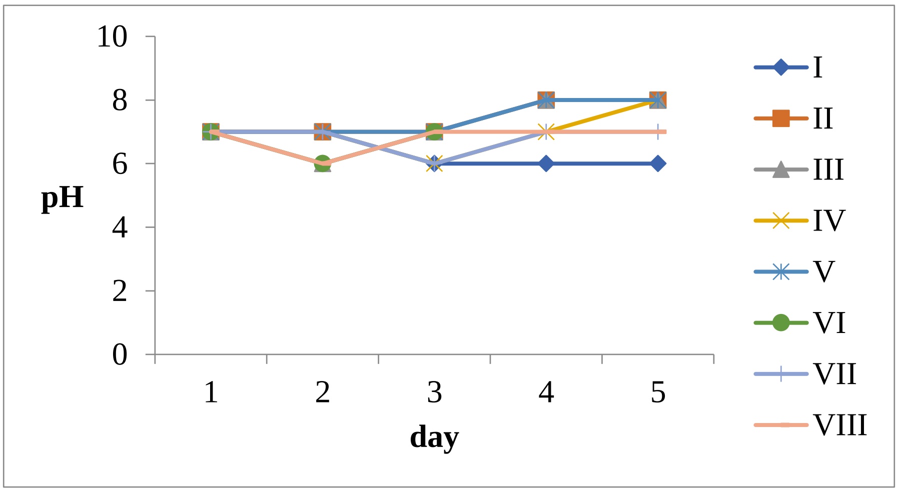

Figure 3. pH graph

Figure 3 shows the fluctuating pH response value. This statement is supported by research by Zakaria (2008) which states that the pH response value of fish which was originally neutral, will eventually become acidic due to the formation of lactic acid from the glycolysis process. Changes in pH response values in fish depend on various factors such as the type of fish, how to catch, feed, and other conditions. This decrease in pH value occurs from the pre-rigor phase to the initial post rigor phase. After that, the pH response value of fish meat will increase to alkaline, due to the formation of alkaline compounds that occur due to protein breakdown, such as NH_3 (ammonia). This compound is what causes the unpleasant odour in fish. This increase in pH response value occurs at the end of the rigor mortis phase.

3.1.4. Texture

Texture is the quality parameters that are influenced by the level of fluid in the body of fish. Determination of texture in this study used a Universal Testing Machine (UTM). The working principle of this machine is the emphasis on body samples. Emphasis will be calculated force (N) that required to push the fish to some extent. If the force (N) indicated greater, so describes texture of fish harder. Value of texture responses skipjack tuna can be shown in figure 4.

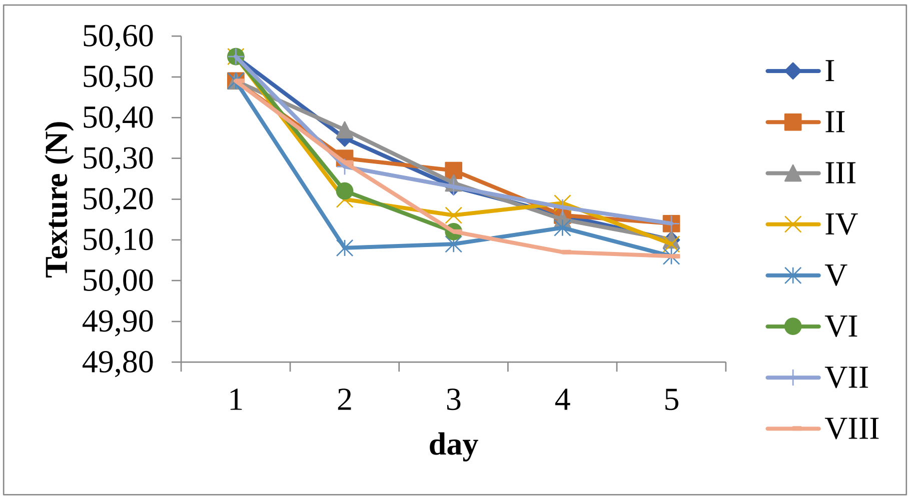

Figure 4. The texture responses (N)

In figure 4 shows the value of texture decreases every day. At the beginning, texture responses are soft. On the fifth day the softest texture of fish is box V and VII of 50.06 N. The statement was supported by research Sayekti (2011) mentions during storage, the texture of fish will be softer over time. Tenderness or loss of elasticity of meat is due to the actomyosin as a result of interaction between actin and myosin proteins. Damaging components of meat causes the release of water bonds so that the meat will lose its ability to hold water. Water will come out of the cells in the form of tiny droplets, causing a watery fish meat. It can be shown also by the results of the water content is increasing every day.

3.1.5. *Total Plate Count* (TPC)

Measuring the level of freshness of fish can be seen from the number of bacteria that thrive on fish. TPC response values can be shown in Figure 5.

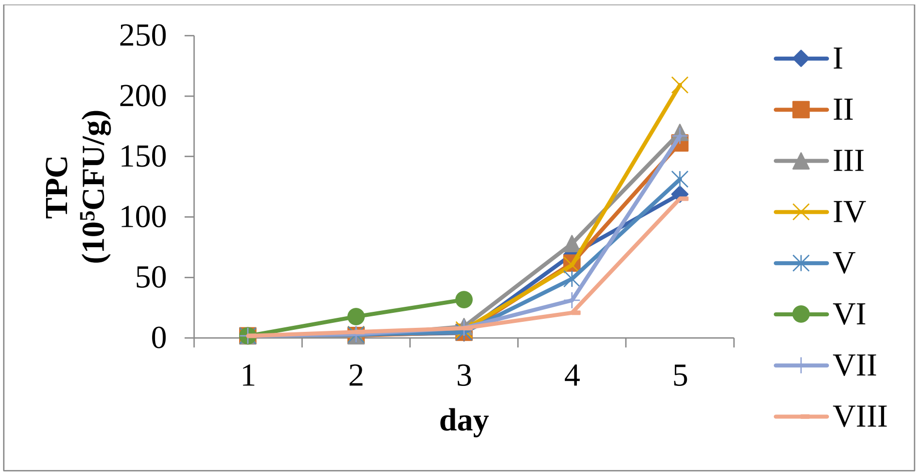

Figure 5. TPC responses

In figure 5 shows the TPC value has increased each day. The highest of TPC value is in the experiment IV with a $209x10^5$ box CFU/g. Meanwhile, the lowest of TPC value is box VIII with $115x10^5$ CFU/g. increasing TPC values indicates that damages fish increased. Accroding to Connel (1990) a high water content in the fish meat is a media for supports the growth of spoilage microbes. It is shown in the test results of water levels every day increasing. In addition to the research conducted by Zakaria (2008) fish meat is sterile because it has an immune system that prevent bacteria from growing in the flesh of fish. After dead, the immune system is not working anymore and bacteria can multiply freely. The process of deterioration caused by bacterial activity would not take place before the end of rigor mortis. At the end of the rigor phase, when decomposition increasingly, bacterial activity began to increase.

3.2 Mean Analysis of Skipjack tuna Quality Response

Mean analysis is an analysis that is used to determine the average value of the product. While the signal to noise is a signal analysis to determine the effect of noise products. In the calculation of S/N ratio, there are some characteristics. Characteristics of peroxide, water content, and total plate count are called smaller the better characteristic, for pH response are a nominal the best characteristics, and for textures is included larger the better characteristics.

The data used for SNR and mean analysis is the third day of data. Because, the third day is the longest storage for all experiments. On the fourth day, box VI should dismissal because the condition of fish had rotten. Table 3 is the result of the calculation of mean values and table 4 is the calculation of S/N Ratio.

Tabel 3. The Calculation of Mean

Experiment	POV (eq/g)	Water Content (%)	pH	Texture (N)	TPC (10^5CFU)
I	0.40	77.45	6.00	50.23	23.50
II	0.21	72.00	7.00	50.27	24.50
III	0.62	73.21	7.00	50.24	24.50
IV	0.46	74.88	6.00	50.16	21.50
V	0.65	74.93	7.00	50.09	23.00
VI	0.59	74.65	7.00	50.12	227.00
VII	0.61	75.56	6.00	50.23	92.50
VIII	0.47	80.31	7.00	50.12	105.50

Tabel 4. The Calculation of S/N Ratio

Experiment	POV	Water Content	pH	Texture	TPC
I	8-96	-36.53	-1.76	34.02	-24.41
II	1.93	-35.90	0.00	34.03	-24.77
III	5.56	-36.04	0.00	34.02	-24.77
IV	7.26	-36.25	-1.76	34.01	-23.64
V	5.34	-36.20	0.00	33.99	-24.23
VI	5.87	-36.17	0.00	34.00	-43.81
VII	5.65	-36.32	-1.76	34.02	-36.32
VIII	7.33	-36.91	0.00	34.00	-37.19

3.3 Comparison of the results Mean and Signal to Noise Ratio Analysis for Skipjack tuna of quality Response

Comparison of the results mean and S/N ratio analysis is intended to determine which factors are able to hold the quality of tuna products during storage. The result of mean and S/N ratio analysis shows that the ranking and factor are same. It can be shown in table 5.

Table 5. Rank of each responses

Rank.	POV		Water content		pH		Texture		TPC	
	Mean	*SNR*	*Mean*	*SNR*	*Mean*	*SNR*	*Mean*	*SNR*	*Mean*	*SNR*
1	C1	C1	F2	F2	G2	G2	A1	A1	A1	A1
2	A1	A1	C2	C2	B1	B1	F2	F2	E2	E2
3	D2	D2	E2	E2	C2	C2	C1	C1	F1	F1
4	B1	B1	A1	A1	D2	D2	D1	D1	D1	D1
5	E2	E2	B1	B1	E1	E1	B2	B2	G2	G2
6	G2	G2	G2	G2	F2	F2	E2	E2	C2	C2
7	F1	F2	D1	D1	A2	A2	G1	G1	B1	B1

Analysis of the mean and S / N ratio can produce a combination of the best level of quality on every response. The optimum combination of levels on each quality response can be shown in Table 6.

Table 6. The Optimum Factors and level

Factors	Level				
	POV	WC	pH	Texture	TPC
A	1	1	2	2	1
B	1	1	1	1	1
C	1	2	2	2	2
D	2	1	2	2	1
E	2	2	1	1	2
F	2	2	2	1	1
G	2	2	2	2	2

3.4 *Analysis of Variance* (Anova) of Skipjack Quality Response

Testing experimental data in this study used ANOVA. ANOVA is a statistical tool in base decisions to detect differences on the average results of the object being tested. In this study, Two-Way ANOVA was used to analyze the variation in the data. Two-Way ANOVA is used for experiments that have two or more factors as well as having two levels or more. ANOVA analysis is done by comparing the value of F table and F calculate. If F calculate < F table, so it can be concluded that these factors are less significant influence on the experiment response. In this study, using 95% confidence level and (F.05; 16; 1), so we get F table 4.49. Below is a calculation of the percent contribution of ANOVA on each tuna products quality response that have been tested are shown in Table 7.

Table 7. The Contribution of ANOVA on each quality response

Faktor	Contribution factor (%)				
	POV	WC	pH	Texture	TPC
A	26,52	15,38	6,25	40,47	31,20
B	13,18	-	-	-	5,46
C	26,52	14,29	6,25	22,98	-
D	19,55	-	6,25	5,27	17,35
E	-	16,75	6,25	-	17,88
F	-	37,25	6,25	26,89	9,25
G	-	-	59,58	-	13,81
error	14,22	16,33	9,17	4,38	4,75

In the table shows different the percentage contribution of responses. In peroxide response, the most significant factors is factor A of 26.52% and C of 26.52%. In water content response is effected by F factor with 37.25%, pH response is factor G with 59.58%, texture response is factor A with 40.47% and TPC response is factor A of 31.20%.

3.5 *Multi-Performance Characteristics*

Quality Response to determine the freshness of fish in this study was peroxide value, water content, pH, texture, and total plate count. This suggests that the study is called a multi-response Taguchi. Multi-response Taguchi is a case that illustrates the quality response are more than one. If only one parameter or response, it is called a single response Taguchi.

The analysis used a multi-performance characteristics with a multi-S/N ratio. Steps in the multiple response analysis is initially calculated loss function of each response in each experiment. Further normalization of the data. The next step is to be weighted to calculate the total loss function. After that, the calculation of multi S/N ratio in each experiment and conducted by making the effect of factors to determine the best level combination. The results of the calculation of multi-performance characteristics shown in figure 6.

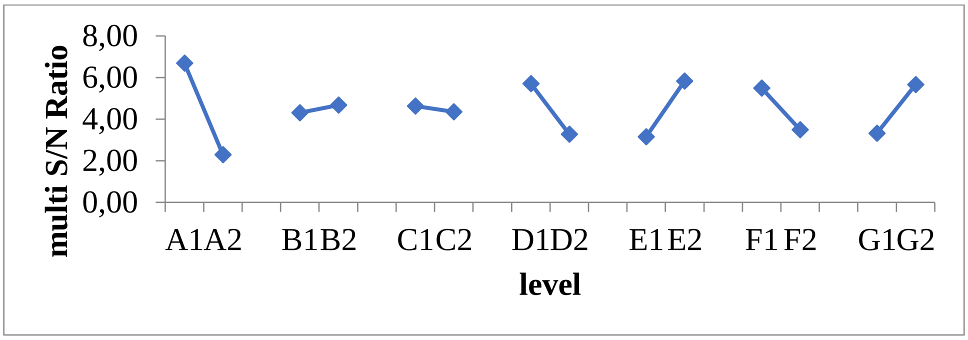

Figure 6. Factor effect of multy S/N ratio

In Figure 6 shows that the difference value factor A has the greatest. Then factor A has a major influence on the quality response of tuna products. Priorities quality factor freshness of the fish in cold storage can use the results of rank value difference. Priorities to consider the storage of fish are A, E, D, G, F, B, and finally C factor.

The most important factor to maintain the freshness is A factor, the weight ratio of ice to fish on the storage box. This factor contributes to reducing the temperature received by the fish. Ice is used to reduce the temperature of the fish. Decrease the temperature the fish is intended to decreasing metabolites activity. Fish are relatively high temperatures, and ice are low-temperature, if they interact, there will be transfer of heat energy at a time until temperature equilibrium will occur. This supported by Rahmawan (2001) which states that if the ice is used more and more, the decreasing temperature fish faster. However, if the ice is used too much, there will be a chilling injury or damage due to tuna product quality, caused the temperature is too cold. Thus, the factor weight ratio of fish and ice is an important factor to maintain the quality of fish products during storage.

The second priority is factor E, the concentration of salt used. In this study salt tha researcher used is NaCl. Salt have function for decreasing freezing point, because the freezing point of salt solution is lower than the freezing point of water. It is also stated by Hadiwoyoto (1993) that the reaction between the salt and ice cause a decreasing temperature.

The third factor is factor D, the form of ice. Forms of ice that researcher used are smooth and cube. Form of ice is related to the ability of ice to cover the body of fish. The larger surface area ice, then the fish can be completely ice covered. This will lead to a drop in temperature could be global fish on the fish, so that deterioration can be slower. It also supported by Masyamsir (2011) that there are various forms of ice have a cooling vary speeds.

The fourth priority is factor G, the number of fish per kilogram. This is related to the surface area of fish. Fish is a food product that shapes and sizes vary even within a single species. At the market level, the number of 1 kilogram of fish is different. Fish size greatly affects the cooling surface area. If the surface area large, the cooling is rapid. Therefore, this study used a variety of fish size per kilogram consist of 4 and 5 fish.

The fifth priority is factor F, the shape of fish. Damaging fish during storage is caused by metabolic activity occurs in the body of fish. According to Junianto (2003) this activity occurred in the digestive, fins, tail and head. Therefore, fishs are weeding before being stored in the cool box.

The sixth priority is to factor B, the size of the box. In this study, fish boxes used to store the fish is made from the styrofoam. Styrofoam is a material made from a developed or expanded polysteryne having very light weight about 13 kg/m^3 to 16 kg/m^3 (Anonymous, 2012). Styrofoam box has a light weight, durable and practical, easy for storage, as well as widely used for fragile goods and fishery products, plantations, ranches and farms. Size box greatly affect the quality of fish products. This relates to the transfer heat energy in and out on the cooling system box.

The last priority is C, a replacement ice. Ice received heat energy from fish or from environment (out of the box system). Temperature of melting ice will change to reach equilibrium temperature to the temperature of fish, which would result in less than the maximum cooling. Therefore, there should be a new replacement ice storage box. Older ice melt from one experiment to another experiment differently, so that the replacement time in each experiment was different. This is supported by Hadiwiyoto (1993) that the replacement of ice time is one good way of cooling to maintain the freshness of the fish.

Priority factors which made it intends to measure the importance of these factors on fish storage in order to keep a good quality product. So that businesses can determine which factors they need to consider the fish cooling using ice during storage.

In figure 6, the best combination according to the calculation of multi S/N ratio is A1, B2, C1, D1, E2, F1, and G2. The Best level is the level which has been a higher SNR. Level the best combination is absent in orthogonal table aray. However, the combination of level approach by considering the priority factor, demonstrated by experiment II. Experiments or box II has a combination of A1, B1, C1, D2, E2, F2 and G2 with 1:1 level, (45x29x14) cm^3, 12 hours, ice cube, 10%, dressed fish, and 5 fishes.

4. CONCLUSIONS

Based on the research results, then there are several conclusions that can be drawn, which is as follows.

a. Priorities to consider the storage of fish in is weight ratio of ice and fish (A), concentration of added salt (E), ice form (D), number of fishes per kg (G), fish form (F), box size (B), and time replacing ice (C).
b. The increase of peroxide value response contributed by factor A with 26.52% and factor C of 26.52%. Decline in the water content response contributed by factor F with 37.25%. Fluctuation in the pH response by the factor G of 59.58%. The increase in the texture responses contributed by factor A of 40.47%. The increase in TPC response contributed by factor A of 31.20%.
c. The best combination level is weight ratio of ice and fish 1:1, box size (45x29x14) cm^3, time replacing ice 12 hours, ice cube, concentration of added salt 10%, fish form: dressed fish, and number of fishes per kg: 5 fishes.

Parameter quality tuna products that have been made still less to determine fish freshness. So that the necessary testing of the other quality parameters.

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