Thesis for the Degree of Master of Fisheries Science

Optimization and Quality Evaluation of Gwamegi Processing from Pacific Saury (*Cololabis Saira*) Using Response Surface Methodology

by

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반응표면법을 이용한 꽁치의 과메기 제조의 최적화와 품질평가

Advisor: Prof. Yang-Bong LEE

by

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Abstract

Gwamegi is a famous traditional local food in Korea with an increasing consumption. To guarantee sustainable development of Gwamegi with improved quality, taste, and sanitation which satisfy consumer need, Gwamegi was produced from Pacific saury with a weight range of (50-100g) using RSM to maximize the response, and experimental design of 15 experimental treatments was used, the effect of humidity (30%, 40% and 50%), Temperature (14°C, 18°C, and 22°C), and time (24hrs, 36 hrs, and 48hrs) on weight loss (%), moisture content (%), TVBN, TMA, and sensory test was evaluated. Using SAS software program, RSREG procedure was performed. Statistical significance was observed at 95% confidential interval. To interpret the data, Maple 17 software was used to design 3-dimensional graph. The coefficient of regression (R^2) and total mean for weight loss, moisture content, TVBN, TMA, fishy smell, Gwamegi smell, smell preference and appearance preference were 0.7422, 0.8104, 0.9360, 0.9495, 0.6983, 0.8385, 0.9636, 0.8181 and 37.30%, 24.21%, 11.29 mg%, 0.39 mg%, 1.85, 1.89, 1.89, 1.98, respectively. Variation for weight loss, moisture content, TVBN, and TMA ranged from 29.79-46.47%,16.8-34.0%,9.8-12.6 mg%, respectively and the score of fishy smell and gwamegi smell were from 1.4 (weak smell) - 2.1(medium smell), preference 1.6(like) – 2.3(neither like nor dislike), and appearance score varied between 1.6 -2.4(medium). Weight loss and moisture response were mostly affected by the order of temperature > humidity > time. TVBN and TMA increase were affected by time > humidity > temperature and humidity > temperature > time, respectively as well as sensory quality where an increase in time and temperature had a negative effect on Gwamegi preference than humidity. The best humidity for the overall evaluated sensory parameter was a humidity 30-45% with low time and temperature. RSM proved to be the effective method for optimizing Gwamegi processing.

Keywords: Gwamegi, Pacific saury, Quality evaluation, Response surface methodology

Introduction

Pacific saury (*Cololabis saira*) is an epipelagic fish, the most important commercial fishes in the northwestern Pacific. In South Korea, it is mostly harvested in North Gyeongsang province in places like Pohang, Uljin, and Yeongdeok. Despite Pacific Saury properties of the weak tissue being a constraint for different processing methods to extend the shelf life, it is commonly consumed as Gwamegi in South Korea. Traditionally Pacific saury and herring are naturally semi-dried, for more than 15 days during winter time until the moisture content reaches about 30% (Kang et al, 2011). Gwamegi is a famous traditional local food with a steadily increasing consumption. According to (Park et al, 2013) improving the quality and sanitation is necessary, to guarantee the sustainable development of Gwamegi with a taste or hygiene which satisfies the people's needs.

Worldwide fish and fishery products are commonly known being an important source nutritious and healthy food as well as a source of livelihood for many millions of people. Especially oily fish such as salmon, tuna, mackerel, and sardine are the richest source of polyunsaturated fatty acids known as eicosapentaenoic acid (EPA, C20:5) and docosahexaenoic acid (DHA, C22:6) (Ariño et al, 2013). (Lee et al. 2003, Mori 2004) reported eicosapentaenoic acid (EPA, 20:5 n-3) and docosahexaenoic acid (DHA, 22:6, n-3) to protect against a wide range of diseases, which includes: atherosclerosis, myocardial infarction, cancer, autism, and sudden death. According to (Kasim-Karakas 2001, Mori

2004, Heller, et al. 2006), they mentioned EPA and DHA along with n-3 fatty acids being beneficial in reducing inflammation, lowering blood pressure, raising low-density lipoprotein (LDL) cholesterol, and decreasing plasma triglyceride (TG).

Fish is one of the exceptional perishable foods and as a result of the globalization of food trade, fish products tend to be more susceptible to rejection due to poor quality (Teklemariam et al, 2015). Therefore, if fish products are not handled and processed correctly the consumer may be at risk. When using drying as a processing method of seafood especially oily fish, chemical and physical properties of fish muscles are affected. Hence, deterioration of quality and nutritional properties of the products. As optimization is a crucial tool in processing for the efficiency of processing operations and acceptability of the product. Response surface methodology(RSM) is recommended by many successful studies in food processing for controlling the effects of independent variables to optimize the response of the dependent variables. (Koç & Kaymak-Ertekin, 2010). Different measures mostly used in seafood quality assessment of dried fish are proximate analysis, total volatile base a measure of amino acid degradation, total viable count, peroxide value and thiobarbituric acid test as a measure of oxidative rancidity and protein digestibility (Bremner, 2002).

Objectives

The present study aims are to provide the quality results of Gwamegi processed using response surface methodology (RSM) with humidity, drying temperature, and time as independent variables. Quality control measures to be evaluated in this study are ones of the above recommended for dried fish. In Chapter 1, weight loss and moisture content are known to influence the quality and microorganism growth will be evaluated in Gwamegi processing. In Chapter 2, VBN and TMA will be evaluated for fishy smell produced during Gwamegi processing, and the sensory test will be performed in Chapter 3.

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Chapter 1

Quality evaluation of weight loss and moisture content during Gwamegi processing using response surface methodology

Abstract

In this study, Gwamegi was processed under 15 different drying conditions based on response surface methodology (RSM). There was no significant difference ($p>0.05$) in the weight loss and moisture content of all treatments during Gwamegi processing. Weight loss and moisture content were analyzed by statistical analysis. The best condition was observed through 3D graphics. Results showed that the values reported for weight loss and moisture were ranged between 29.79% - 46.47% and 16.8% - 34% for Gwamegi from 15 drying conditions, respectively. From statistical results, weight loss showed R^2 and the total mean of 0.7422 and 37.30%, respectively; moisture 0.8104 and 24.21%, respectively. Also, RSM results showed that the order of temperature > humidity > time elucidated an influencing effect on weight loss and moisture response.

Keywords: Gwamegi, weight loss, moisture, RSM, Pacific saury

Introduction

Gwamegi processing is based on drying method known as a process of removing water by physical removal. The water content in fish is a good environment for chemical and microbial reaction and microorganisms' growth. As stated by Doe (1998), drying process mostly depends on temperature, humidity together with time depending on the type of fish and its preparation. Trying to dry rapidly can have undesirable effects. Fish drying understood as a physical process is known as a convective mass transfer that affects the fish. Once its surface is exposed to air and begins to dry as moisture evaporates from its surface into the air. Evaporation proceeds until there is no free water to the surface. At that instant, a moisture gradient is established to the surface and cause interior water to move towards the surface with time. This influences the moisture concentration gradient to gently decrease. Hence the water transport decreases and the drying rate slows down continuously until the fish is at its equilibrium moisture content. The rate of the evaporation is primarily governed by the humidity of the air stream, its speed, drying temperature and time (Bremner, 2002).

Physical change is a crucial concern in order to control the quality of processed fish by drying methods. The variation in weight loss influences changes in moisture content and water activity (a_w) which contribute to fish spoilage by facilitating microbial growth. Water content or moisture affects food stability, inherent quality, and processing potential.

An intimate functional relationship exists between water and other component substances such as proteins, fat, and glycogen in living tissues; this balance plays a crucial role in the biochemistry of all living organisms (Woyewoda et al., 1986). At the time the physical changes are mostly affected by weight loss and moisture content. Therefore, the two are to be evaluated as for quality parameters in Gwamegi processing using response surface methodology (RSM).

Materials and Methods

Samples Preparation

Prior to processing of frozen Pacific saury (*Cololabis saira*) with a weight range of (50-100g) purchased from a fish market, pretreatment such as de-scaling, de-gutting was done, and bones along with internal organs were removed and the fillet remained. In order to prevent propagation of microbes after the pretreatment, saury was immediately washed 3 times with tap water. Then it was suspended on the rod for 3 hours for water drainage. It was dried under controlled conditions based on response surface methodology (RSM) which is used to give results providing direction when doing several experiments.

Experimental Design

The experimental design of this study was based on three independent variables such as humidity (%), temperature (ºC), and time (hrs) as shown in Table 1. Table 2 contains details on the used factorial design (3 independent variable x 3 interval x 15 runs) in this experiment.

Table 1. Independent variable, controlled variable and dependent variable for the experiment

Independent Variable	Controlled Conditions			Dependent Variable
RSM	-1	0	+1	Weight loss Moisture content VB, TMA Sensory Evaluation
Humidity(%)	30±3	40±3	50±3	
Temperature(℃)	14	18	22	
Time(Hrs)	24	36	48	

Table 2. Coded variables and their real values in 3x3x15 factorial design

No	Coded			Uncoded		
	Humidity	Temperature	Time	Humidity	Temperature	Time
1	+1	+1	0	50±3	22	36
2	+1	-1	0	50±3	14	36
3	+1	0	+1	50±3	18	48
4	+1	0	-1	50±3	18	24
5	-1	+1	0	30±3	22	36
6	-1	-1	0	30±3	14	36
7	-1	0	+1	30±3	18	48
8	-1	0	-1	30±3	18	24
9	0	+1	+1	40±3	22	48
10	0	+1	-1	40±3	22	24
11	0	-1	+1	40±3	14	48
12	0	-1	-1	40±3	14	24
13	0	0	0	40±3	18	36
14	0	0	0	40±3	18	36
15	0	0	0	40±3	18	36

Determination of weight loss

Samples were weighed before and after processing for weight loss determination. For further calculation the following formula was used:

$$\textbf{Weight loss} = (W_1 - W_2)/W_1 x100$$

W_1= weight of sample before drying

W_2 = weight of sample after drying

Determination of moisture content

The moisture content of the samples was determined by using 4 g of the grinded Gwamegi then dried in an oven at a temperature of 105ºC for 10 hours to reach the constant weight. Before and after weight was used for moisture content determination, which was expressed as a percent using the following formula:

$$MC = \frac{W1 - W2}{W1} \text{ x } 100$$

W_1= weight of sample before drying

W_2 = weight of sample after drying

Statistical Analysis

Using SAS software program (version 9.4) the statistical analysis of RSM (Response Surface Methodology) was carried out using the RSREG procedure and the statistical significance was observed at 95% confidential interval. Then, Maple 17 was used to interpret the response in the 3-dimensional graph.

Results and Discussion

Weight loss

In all processed samples as presented Table 3, a sample produced under a humidity of 40% at 22°C of temperature for 24hrs resulted in a minimum weight loss of 29.79% and a sample produced under a humidity of 30% at 22°C of temperature for 24hrs resulted in a maximum weight loss of 46.47%. This difference can be explained by effects of differences in drying condition, although results were within the range that occurred in a research done by Olokor et al (2009). They reported that weight loss in solar dried fish was influenced by humidity, radiation, and temperature and that fish weight loss was observed to be highest in the Northeast (63%) and lowest in the South-south (27%). Different method and condition of drying are responsible for differences which occur in the final product, which can explain differences in the two study. All samples processed under RSM condition resulted in a mean weight loss of 37.30% and R-square value of 0.7422 in Table 4. There was no significant difference ($p>0.05$) in the weight loss of all treatments during Gwamegi processing. To explain the effect of different factors used to control the drying conditions, Table 5 was used to generate a formula below used in Maple17 to generate 3D graphic design where 2 different factors were compared and one was fixed.

Weight loss (%) = $7.7492708 - 0.313958 * x_1 + 1.008438 * x_2 + 1.378229 * x_3 +$

$0.002267 * x_1 * x_1 - 0.011625 * x_2 * x_1 - 0.011771 * x_2 * x_2 +$

$0.002479 * x_3 * x_1 + 0.005677 * x_3 * x_2 - 0.017784 * x_3 * x_3$

Table 3. Moisture content of Gwamegi processed under different conditions

	Uncoded			Response Function
Treatment	Humidity	Temperature	Time	Weight Loss (%)
1	50±3	22	36	38.54±3.2
2	50±3	14	36	31.83±1.6
3	50±3	18	48	37.63±3.0
4	50±3	18	24	31.89±0.8
5	30±3	22	36	46.47±7.1
6	30±3	14	36	37.90±1.6
7	30±3	18	48	40.14±3.2
8	30±3	18	24	35.59±0.8
9	40±3	22	48	39.55±4.3
10	40±3	22	24	29.79±0.4
11	40±3	14	48	41.46±6.3
12	40±3	14	24	32.79±2.2
13	40±3	18	36	38.05±0.1
14	40±3	18	36	39.03±0.4
15	40±3	18	36	38.86±0.3

The value is averaged ± standard deviation (n=2).

Table 4. Statistical analysis of weight loss in Gwamegi processing

Response Surface for Variable Weight loss	
Response Mean	37.301333
Root MSE	3.670720
R-Square	0.7422
Coefficient of Variation	9.8407

Table 5. Coefficient regression model estimated by the RSREG procedure for weight loss

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	7.792708	71.827279	0.11	0.9178	38.646667
humidity	1	-0.313958	1.826929	-0.17	0.8703	-2.526250
temperature	1	1.008438	4.882929	0.21	0.8445	1.296250
time	1	1.378229	1.331163	1.04	0.3480	3.590000
humidity*humidity	1	0.002267	0.019103	0.12	0.9102	0.226667
temperature*humidity	1	-0.011625	0.045884	-0.25	0.8101	-0.465000
temperature*temperature	1	-0.011771	0.119394	-0.10	0.9253	-0.188333
time*humidity	1	0.002479	0.015295	0.16	0.8776	0.297500
time*temperature	1	0.005677	0.038237	0.15	0.8878	0.272500
time*time	1	-0.017784	0.013266	-1.34	0.2378	-2.560833

Independent variables used in controlling drying condition were x_1= humidity, x_2= temperature, and x_3= time. As time and temperature increased, weight loss in Gwamegi increased as well. Gwamegi weight loss was highly affected by the drying time, but the drying temperature didn't show a big impact (Figure 1-A). Figure 1-B compares the effect between drying time and humidity on Gwamegi weight loss. As time was increasing, weight loss was increasing. As the humidity was increasing, weight loss was reducing. A big weight loss was observed at 24 hrs and humidity of 30% considered as the lower value of the two factor. As time passed, weight loss increased with the increased humidity and then weight loss continuously decreased. Temperature and humidity effects on weight loss are presented in Figure 1-C. At a low temperature of 14°C and humidity of 30%, there was a high increase in weight loss. As temperature increases, weight loss continuously increased, but weight loss decreased as humidity increases.

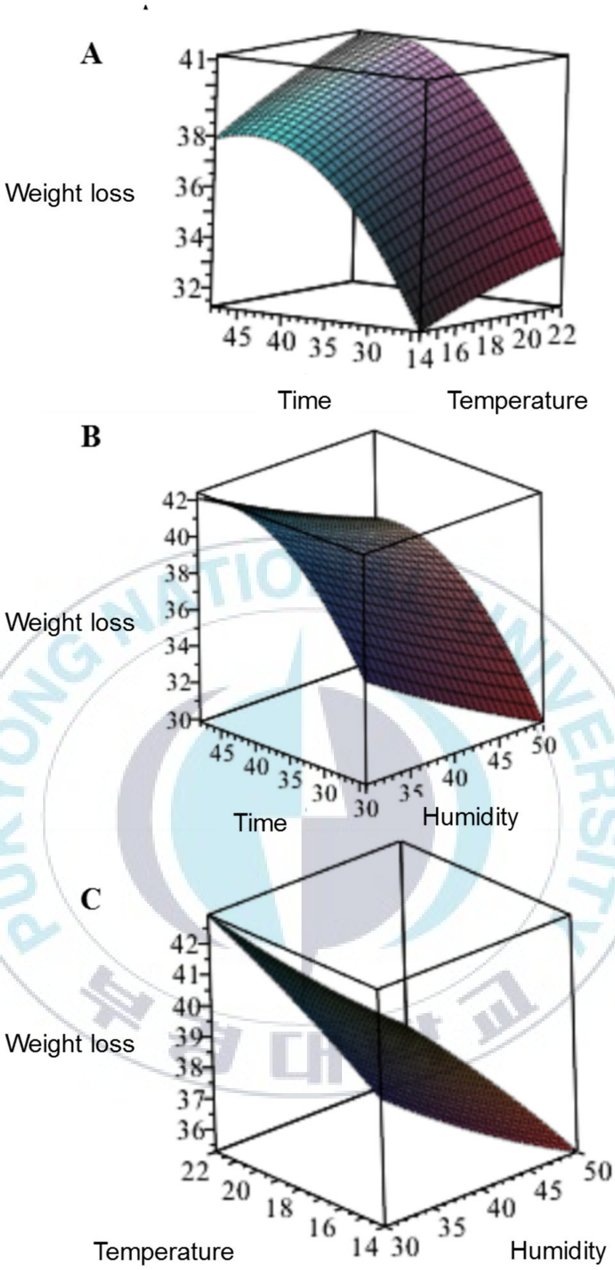

Figure 1. Three dimensional response surface plots showing interactive (A) drying time and temperature, (B) drying time and humidity, and (C) drying temperature and humidity on weight loss in Gwamegi processing.

Moisture content

Moisture content in Gwamegi samples produced under different conditions varied between 16.8% for a sample dried under a humidity of 40% at a temperature of 18°C during 36 hrs and 34% in a sample dried under a humidity of 40% at 18°C of temperature for 24 hrs (Table 6).

Table 6. Moisture content of Gwamegi processed under different conditions

	Uncoded			Response Function
Treatment	Humidity	Temperature	Time	Moisture content (%)
1	50±3	22	36	18.8±0.5
2	50±3	14	36	27.8±0.8
3	50±3	18	48	28.5±0.8
4	50±3	18	24	19.4±0.5
5	30±3	22	36	19.6±0.6
6	30±3	14	36	29.4±0.8
7	30±3	18	48	18.5±0.5
8	30±3	18	24	30.4±0.9
9	40±3	22	48	18.4±0.5
10	40±3	22	24	23.4±0.7
11	40±3	14	48	26.7±0.8
12	40±3	14	24	34.0±1.0
13	40±3	18	36	22.4±0.6
14	40±3	18	36	16.8±0.5
15	40±3	18	36	28.4±0.8

The value is averaged ± standard deviation (n=2).

This study falls within the range of the funding of Huang et al (2017) where the measured moisture contents at different dehydrated levels of scallops were within a wide range of 17.99%–66.73%. The lower moisture content can be considered as a success of RSM drying method as Rana & Chakraborty (2016) mentioned that with storage time moisture increase with storage time, increase in moisture content affect the quality deterioration of the product. In Table 7., the R-square value was 0.8104 and the total mean of moisture content in all samples was 24.21%. There was no significant different ($p>0.05$) in the moisture content of all treatments during Gwamegi processing but the interaction between time and humidity showed significant difference ($p<0.05$). In a study conducted by (Ali et al. 2011), moisture content was lower than found in this study. For smoked-dried fish moisture varied between 7.58±1.13% and 8.95±1.73% and for sun-dried fish, it varied between 11.5±0.71% and 14.06±2.11%. Based on Table 8, the below formula was generated for 3D graph design in Maple software to show the relationship among independent variables by affecting the moisture content in processed fish.

$$\text{Moisture content (\%)} = 168.202812 - 1.684000 * x_1 - 4.930625 * x_2 - 2.961875 * x_3 - 0.000363 * x_1 * x_1 + 0.005312 * x_2 * x_1 + 0.086172 * x_2 * x_2 + 0.043792 * x_3 * x_1 + 0.012083 * x_3 * x_2 + 0.011606 * x_3 * x_3$$

Table 7. Statistical analysis of moisture content in Gwamegi processing

Response Surface for Variable Moisture	
Response Mean	24.167333
Root MSE	3.968786
R-Square	0.8104
Coefficient of Variation	16.4221

Table 8. Coefficient regression model estimated by the RSREG procedure for moisture

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	168.202812	77.659721	2.17	0.0826	22.560000
humidity	1	-1.684000	1.975277	-0.85	0.4328	-0.408750
temperature	1	-4.930625	5.279428	-0.93	0.3932	-4.723750
time	1	-2.961875	1.439255	-2.06	0.0947	-1.885000
humidity*humidity	1	-0.000363	0.020654	-0.02	0.9867	-0.036250
temperature*humidity	1	0.005312	0.049610	0.11	0.9189	0.212500
temperature*temperature	1	0.086172	0.129089	0.67	0.5340	1.378750
time*humidity	1	0.043792	0.016537	2.65	0.0455	5.255000
time*temperature	1	0.012083	0.041342	0.29	0.7818	0.580000
time*time	1	0.011606	0.014343	0.81	0.4552	1.671250

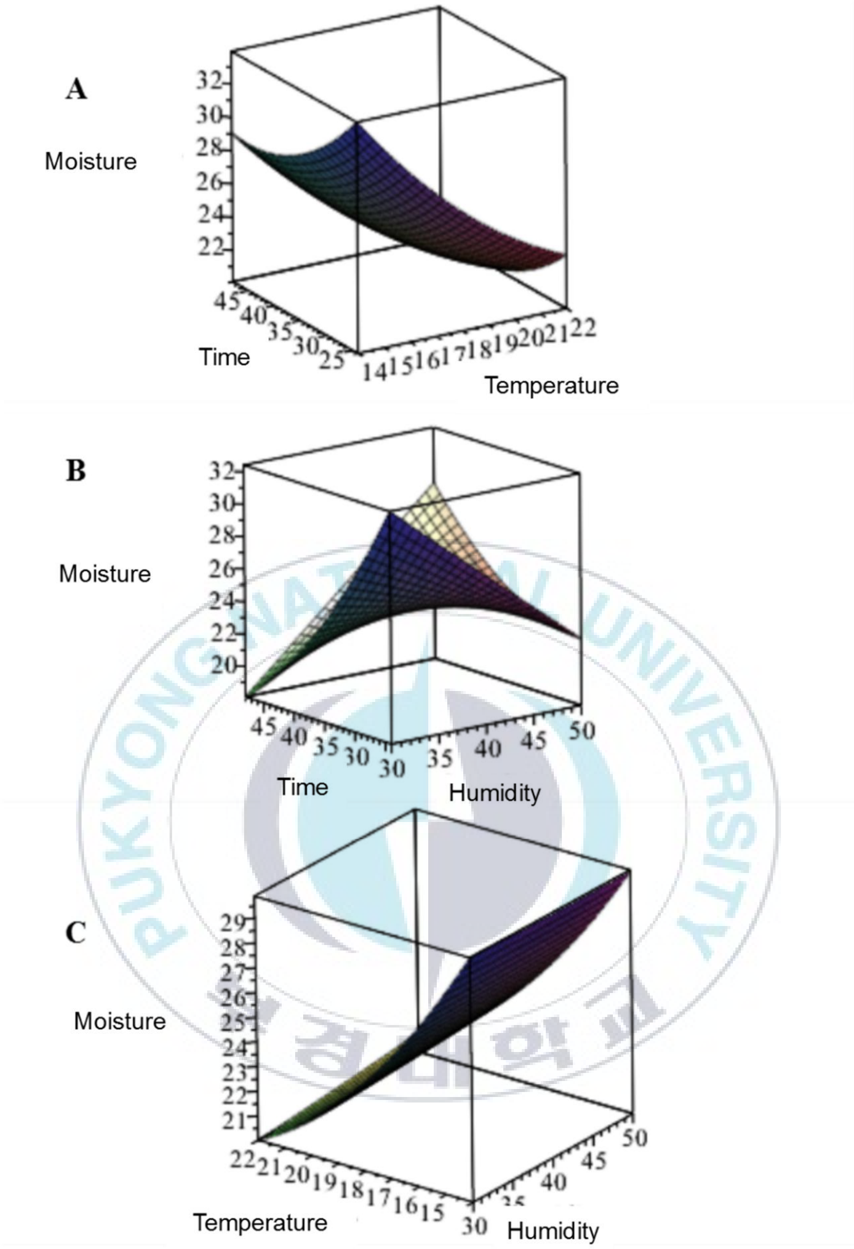

Figure 2. Three dimensional response surface plots showing interactive (A) drying time and temperature, (B) drying time and humidity, and (C) drying temperature and and humidity on moisture in Gwamegi processing.

Independent variables used in controlling drying condition where x_1= Humidity, x_2= Drying temperature, and x_3= Drying time. With the humidity fixed at 40%, drying time and temperature-increasing effect on the moisture content of dried Gwamegi in (Figure 2-A) shows that as both drying time and temperature were increased, moisture content were reduced. Drying time compared to drying temperature didn't affect much the moisture content. With moisture content decreased with the fixed drying temperature at 18°C, time and humidity increasing. Time increases affected continuously moisture content until the lower value attained. At a fixed time of 36hrs (Figure 2-C) shows effect exhibited by Temperature and Humidity on moisture content. The continuous decrease in moisture content along with temperature and humidity increases was observed.

Conclusion

The response surface methodology was used to investigate weight loss and moisture content in Gwamegi processing. Statistical analysis of the response showed that as temperature increased, weight loss continuously increased, but as humidity increased, weight loss decreased. The continuous decrease in moisture content along with temperature and humidity increases at the fixed time of 26 hrs was observed. Both weight loss and moisture were mostly affected by temperature and humidity. This explains the interdependency of weight loss and moisture content.

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Chapter 2
Chemical evaluation of fishy smell during Gwamegi processing using response surface methodology with TVBN and TMA

Abstract

The study was conducted to check sensory quality based on fishy smell during Gwamegi processing using response surface methodology. Total volatile basic nitrogen (TVBN) was evaluated using titration method and Conway unit and measurement of trimethyl amine (TMA) was done by using gas chromatography-flame ionized detector. The measured TVBN and TMA were within the range of 9.8–12.6 mg% and 0.22-0.81 mg%, respectively and from statistical analysis, R^2 values and total means for both TVBN and TMA were 0.9360, 11.29 mg% and 0.9495, 0.39 mg%, respectively. There was a significant difference ($p<0.05$) in the TVBN of all treatments explained by the significance of drying time parameter caused significance between drying time and humidity. There was no significant difference ($p>0.05$) in the TMA of all treatments during Gwamegi processing. TVBN and TMA increases were affected by the order of drying time > humidity > drying temperature and by the one of humidity > drying temperature > drying time, respectively.

Keywords: Gwamegi, RSM, TVBN, TMA

Introduction

During fish spoilage, a variety of traces and volatile bases are produced like ammonia and other chemically known compounds such as amines of trimethyl amine (TMA) and dimethyl amine (DMA). They are called as the volatile basic nitrogen with corresponding names such as total volatile basic nitrogen, total volatile nitrogen or (VBN, tVBN or TVN) which is the total amount of ammonia, dimethyl amine, trimethyl amine and other volatile basic amines. This is used as a parameter to evaluate the degree of spoilage in fish and seafood products because it increases with the progress of spoilage.

Different factor affects fish quality during processing. Most marine fish contain a substance called as trimethyl amine oxide (TMAO). Its decomposition in fish caused by bacterial activity results in an organic compound called trimethyl amine (TMA). TMA is colorless, hygroscopic, and flammable tertiary amine with a strong fishy odor in low concentration and an ammonia-like odor at high concentrations. Certain bacteria that occur naturally on the skin and in the guts of fish and in sea water can break down TMAO to TMA. Woyewoda et al (1986) mentioned that TMA is produced as a result of the bacteria spoilage in fish, so it is an indicator of the degree of spoilage. The various study has been conducted on Gwamegi with the main purpose of quality control to avoid consumer contamination. To improve commercial quality of Gwamegi and provide standardized basic data of marine processed foods, Kang et al (2011) performed a study investigating the physical, chemical, and microbial characteristics of Gwamegi. Parameters such as TMA, VBN, POV, acid value were evaluated and the study concluded that VBN and TMA indices can be controlled and used as a freshness index for Gwamegi. The aim of this study is to perform an evaluation of fishy smell in Gwamegi processing. Being the influencing factor of a fishy smell, volatile basic nitrogen, and trimethyl amine levels will be evaluated as for quality parameters in this study.

Materials and Methods

Gwamegi processed in Chapter 1 based on response surface methodology (RSM) was used in this study for the evaluation of chemical content generating the fishy smell such as total volatile basic nitrogen (TVBN) and trimethylamine (TMA).

Determination of TVBN

Processed Gwamegi was blended for TVBN determination and 10 gram of the sample was homogenized in 50 mL distilled water, centrifuged for 30 min and filtered using filter paper (CHM cat no. F1001-185). The solution from the filtration was used to make test liquid by making a 100ml solution with distilled water using a mass flask. Using Conway unit

(Figure 3) 1.0 mL of test liquid was dropped in the bottom of outer well (Figure 3-B), 1.0 mL of 0.01N-NaOH in inner well (Figure 3-C), 1.0 mL of K_2CO_3 of saturated solution in inner well (Figure 3-A) and vaseline was applied at contact part of the cover plate and outer well then covered and fixed by a clip. The Conway unit was shaken to mix the outer well solution and left at 40ºC for 30 minutes. After that 1 drop of Brunswick indicator was added in the inner cell of Figure 3-C. Then, it was titrated with 0.01N-NaOH using a burette until it went to green. It was repeated two times and the average value was calculated. The experiment of a blank sample was also done using distilled water in place of the test liquid. Using the following formula, VBN calculation was done:

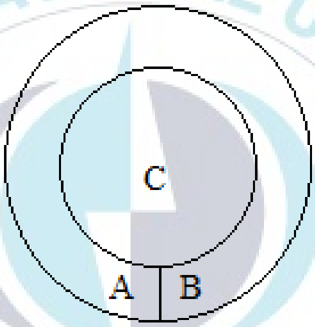

Figure 3. Conway unit.

$$\textbf{TVBN(mg/100g)} = \mathbf{0.14} \times \frac{(b-a)F}{W} \mathbf{x\ 100\ x\ d}$$

w: weight of the sample

F: Factor of 0.01 N-NaOH

d: Dilution rate

0.14: is amount of TVBN (mg) to 0.01 N-H_2SO_4 1ml

a: Blank amount

b: The titration amount

Determination of TMA

Determination of TMA using gas chromatography-flame ionized detector (GC-FID) which reported efficient for the test by Myung-Cheol, et al (1997) was done as follows: To make a sample test, Gwamegi was grinded and to prepare 25% NaOH solution, 100 mL of distilled water and 25 g of NaOH was weighed and mixed. Then, 3g of the grinded samples and 3 mL of NaOH solution were weighed, respectively and mixed into a vital bottle. Then, it was incubated at 10ºC. After 7 min of incubation 250μL gas was taken from the headspace of the vial bottle with a syringe and injected into GC-FID. The result was drawn with the peak area of TMA on the computer after 20 minutes of analyzing.

Statistical Analysis

Using SAS software program (version 9.4) the statistical analysis of RSM (Response Surface Methodology) was carried out using the RSREG procedure and the R-square (R^2) was obtained to confirm the good fit of the model used. In measuring the goodness of fit, the higher the value of R^2 the better predictability (Makkeasorn et al, 2008). The relationship between the model and its value improves when the value of R^2 approaches 1.0 (Duffy et al., 1994). Maple 17 was used to interpret data in the 3-dimensional graph.

Results and Discussion

TVBN

Results of total volatile basic nitrogen (TVBN) in all 15 samples of Gwamegi are displayed in Table 9. The same value of TVBN was 9.8 in 2 samples dried under the same humidity of 30% and the same duration of 36 hrs at distinct temperatures such as 22°C and 14°C. The another same one of TVBN was 12.6 in 2 samples dried at the same humidity and duration of 30% and 48 hrs at different drying temperatures of 22°C and 14°C. This was lower than the results of Kang et al (2011). They reported that the TVBN contents in Gwamegi were in the range between 22.4, 21.5 and 21.8 mg%. Normally the higher TVBN can explain the lower the freshness of the product as well as its quality according to Lee et al (1987). The amount of TVBN in samples was from the drying process. Displayed results in Table 10 show that R-square value was 0.9360 and the Total mean of TVBN was 11.29 mg%. In Table 11, there was a significant difference ($p<0.05$) in the TVBN of all treatments explained by the significance of the parameter of drying time which caused a significant difference in the cross product between drying time and humidity. Results in Table 11 was used to develop the below formula. Maple 17 for 3D graph design shows the relationship between two variables with one fixed.

$$\text{TVBN (mg\%)} = 23.209375 - 0.210000 * x_1 + 0.525000 * x_2 - 0.831250 * x_3 - 0.002625 * x_1 * x_1 + 0.008750 * x_2 * x_1 - 0.02344 * x_2 * x_2 + 0.008750 * x_3 * x_1 + 0.003646 * x_3 * x_2 + 0.006684 * x_3 * x_3$$

Table 9. TVBN in Gwamegi processed under different conditions

Treatment	Uncoded			Response Function
	Humidity	Temperature	Time	VBN (mg %)
1	50±3	22	36	11.9±0.11
2	50±3	14	36	10.5±0.12
3	50±3	18	48	14±0.04
4	50±3	18	24	10.5±0.01
5	30±3	22	36	9.8±0.01
6	30±3	14	36	9.8±0.08
7	30±3	18	48	11.2±0.01
8	30±3	18	24	11.9±0.05
9	40±3	22	48	12.6±0.06
10	40±3	22	24	10.5±0.05
11	40±3	14	48	12.6±0.07
12	40±3	14	24	11.2±0.01
13	40±3	18	36	11.2±0.04
14	40±3	18	36	10.5±0.01
15	40±3	18	36	11.2±0.01

The value is averaged ± standard deviation (n=2).

Table 10. Statistical analysis of VBN content in Gwamegi processing

Response Surface for Variable VBN	
Response Mean	11.293333
Root MSE	0.486655
R-Square	0.9360
Coefficient of Variation	4.3092

Table 11. Coefficient regression model estimated by the RSREG procedure for VBN

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	28.255208	9.522687	2.97	0.0313	10.966667
humidity	1	-0.303333	0.242210	-1.25	0.2658	0.525000
temperature	1	0.262500	0.647367	0.41	0.7019	0.087500
time	1	-0.889583	0.176482	-5.04	0.0040	0.787500
humidity*humidity	1	-0.001458	0.002533	-0.58	0.5897	-0.145833
temperature*humidity	1	0.008750	0.006083	1.44	0.2098	0.350000
temperature*temperature	1	-0.020052	0.015829	-1.27	0.2610	-0.320833
time*humidity	1	0.008750	0.002028	4.32	0.0076	1.050000
time*temperature	1	0.003646	0.005069	0.72	0.5042	0.175000
time*time	1	0.007494	0.001759	4.26	0.0080	1.079167

The results are displayed in Figure 4. Figure 4-A shows how both drying time and temperature affect TVBN content in Gwamegi. At the fixed humidity of 40% as drying time increased, TVBN amount was decreased and it was remained constant between 30 hrs and 35 hrs. Above the drying time, uninterruptable rise was observed. In drying temperature side a slight rise in TVBN was observed until it reached its maximum at 18°C. Beyond the temperature TVBN amount decreased to an initial level. The influence of drying time on TVBN is in agreement with Gwak & Eun's (2010) studies. When Gulbi was manufactured by sun-drying (the control), it had the highest TVBN values and the TVBN of hot-air dried Gulbi increased with the increased drying time at all temperatures.

With the fixed temperature at 18°C, the effects of drying time and humidity on TVBN are shown in Figure 4-B. As drying time and humidity increased, TVBN was decreased, but TVBN at between 35 hrs and 40 hrs was at its minimum level. As drying time went beyond 40 hrs, TVBN increased. At the fixed drying time of 36 hrs, TVBN result on the independent variables of drying temperature and humidity is shown in Figure 4-C. The increase of drying temperature at its initial humidity of 30% caused a continuous decrease in TVBN at the fixed time of 36 hrs. However, an increase of humidity produced an increase in TVBN. From Figure 4, one can say that the low TVBN was at the drying time below 40 hrs, drying temperature between 14-22°C and a humidity of 30%. The most effective factor in TVBN was drying time followed by humidity and drying temperature.

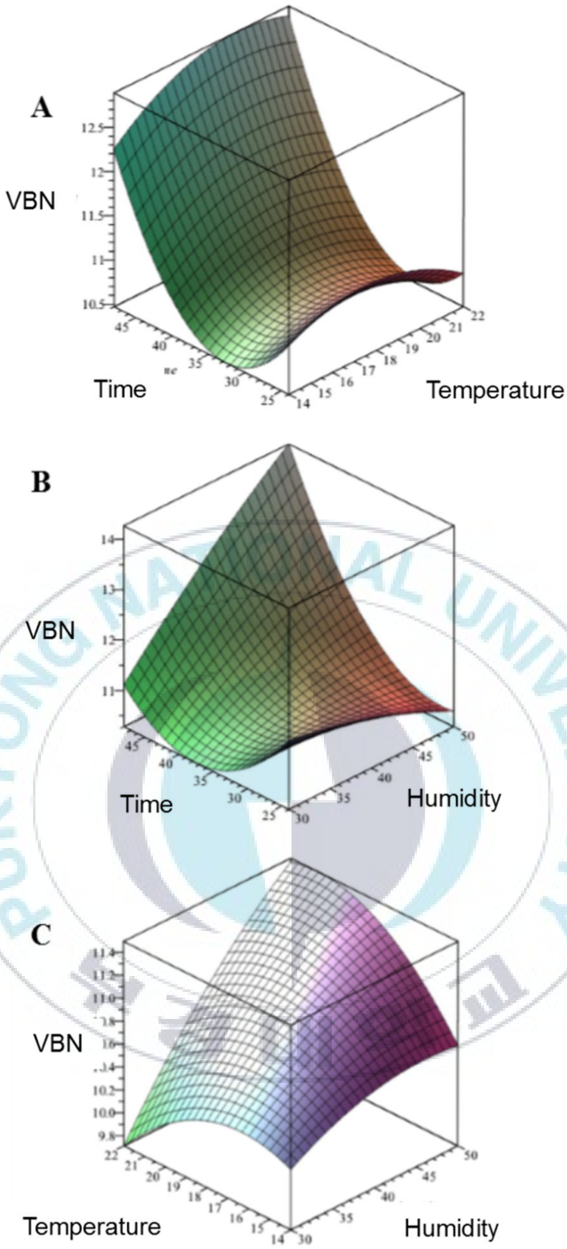

Figure 4. Three-dimensional response surface plots showing interactive (A) drying time and temperature, (B) drying time and humidity and (C) drying temperature and humidity on TVBN in Gwamegi processing.

TMA

TMA concentrations of 15 samples of Gwamegi produced under RSM condition were measured. Results presented in Table 12 show that a minimum TMA of 0.22 mg% was observed in sample dried under condition with humidity of 30%, 14°C for 36 hrs and the maximum TMA of 0.81 mg% was detected by maintaining drying time at 36 hrs and by changing humidity and drying temperature as follow 50% and 22°C. Kang et al's (2011) studies on Gwamegi showed higher TMA values where they were 2.9, 2.6 and 3.6 mg% for 3 different drying types. This may explain the improved quality of Gwamegi from the drying process used in this study. Rising humidity and drying temperature produced an increment in TMA, which explains why a high amount of TMA was observed with an increase in humidity. From Table 13, the value of R-square and the total mean of TMA was 0.9495 and 0.39 mg%, respectively. In Table 14, there was no significant difference ($p>0.05$) in the TMA of all treatments during Gwamegi processing, but humidity showed a significant difference ($p<0.05$). With the results of Table 14, the below formula was obtained. Maple 17 was used to design 3D graphics.

$$\text{TMA (mg\%)} = 1.472812-0.122487* x_1 +0.036094* x_2 +0.023510* x_3 +0.001650* x_1 * x_1 +0.001350* x_2 * x_1 -0.001625* x_2 * x_2 -0.000452* x_3 * x_1 - 0.000120* x_3 * x_2 -0.000078125* x_3 * x_3;$$

Changes of TMA content on drying time and temperature with the fixed humidity at 40% are shown in Figure 5-A. The increase of drying time influenced the decline of TMA amount and in contrary with a boost in drying temperature, TMA undeviatingly increased.

Table 12. TMA in Gwamegi processed under different conditions

No	**Humidity**	**Temperature**	**Time**	**TMA, mg%**
1	50±3	22	36	0.81±0.01
2	50±3	14	36	0.41±0.01
3	50±3	18	48	0.58±0.03
4	50±3	18	24	0.79±0.01
5	30±3	22	36	0.42±0.01
6	30±3	14	36	0.22±0.01
7	30±3	18	48	0.27±0.03
8	30±3	18	24	0.27±0.01
9	40±3	22	48	0.35±0.01
10	40±3	22	24	0.37±0.02
11	40±3	14	48	0.22±0.06
12	40±3	14	24	0.22±0.02
13	40±3	18	36	0.33±0.03
14	40±3	18	36	0.32±0.02
15	40±3	18	36	0.33±0.01

Table 13. Statistical analysis of TMA content in Gwamegi processing

Response Surface for Variable TMA	
Response Mean	0.393133
Root MSE	0.071374
R-Square	0.9495
Coefficient of Variation	18.1552

Table 14. Coefficient regression model estimated by the RSREG procedure for TMA

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	1.472812	1.396620	1.05	0.3399	0.325000
humidity	1	-0.122487	0.035523	-3.45	0.0183	0.175375
temperature	1	0.036094	0.094944	0.38	0.7194	0.109125
time	1	0.023510	0.025883	0.91	0.4054	-0.028250
humidity*humidity	1	0.001650	0.000371	4.44	0.0068	0.165000
temperature*humidity	1	0.001350	0.000892	1.51	0.1907	0.054000
temperature*temperature	1	-0.001625	0.002322	-0.70	0.5152	-0.026000
time*humidity	1	-0.000452	0.000297	-1.52	0.1889	-0.054250
time*temperature	1	-0.000120	0.000743	-0.16	0.8783	-0.005750
time*time	1	-0.000078125	0.000258	-0.30	0.7742	-0.011250

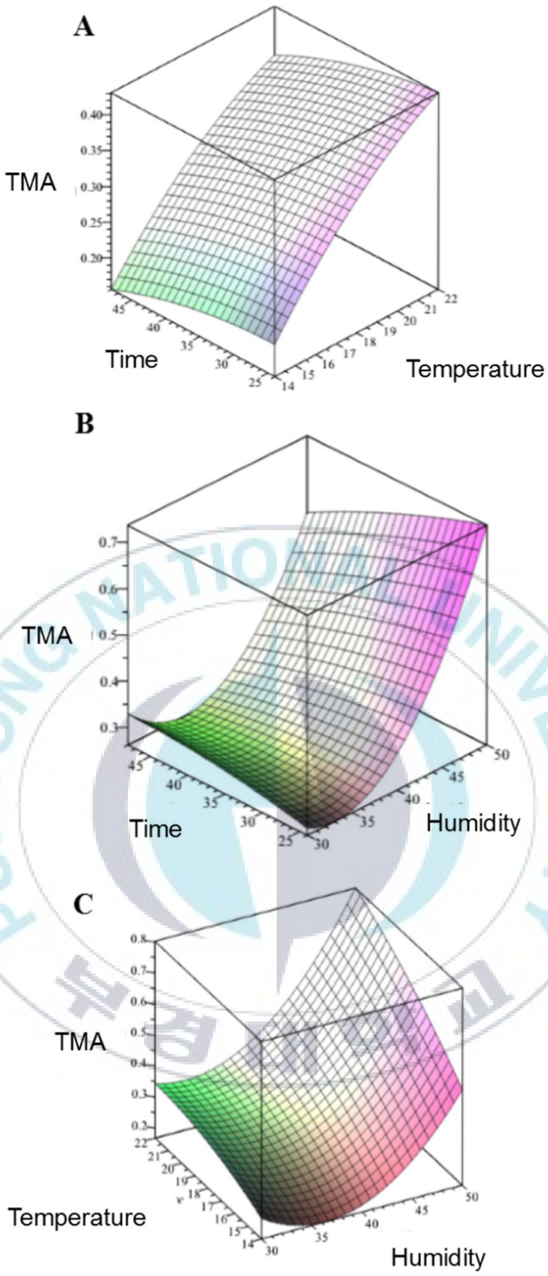

Figure 5. Three-dimensional response surface plots showing interactive (A) drying time and temperature, (B) drying time and humidity and (C) drying temperature and humidity on TMA in Gwamegi processing.

Figure 5-B presented how TMA was affected by the variation of drying time and humidity with the fixed temperature at 18°C. With the increased drying time, variation in TMA was a minor increase. However, with an increment of humidity at a certain level between 30% and 35%, TMA didn't increase, although, with the humidity above 35%, TMA was constantly increased. Effect of drying temperature and humidity on TMA at the fixed drying time of 36 hrs is presented in Figure 5-C. With an increase in drying temperature, a slight increase in TMA was observed. With the increased humidity from 30% to 35, TMA decreased along with the humidity within the range of 35% - 40%, TMA remained constant. With the humidity beyond 40%, TMA increased.

Conclusion

In Gwamegi processing using response surface methodology (RSM), its statistical results showed that increase in VBN was influenced by drying time followed by humidity and drying temperature and increase in TMA was influenced by humidity followed by drying temperature and time. However, there is a correlation between VBN and TMA as they were both lower compared to another study. Therefore, this model is recommended for Gwamegi processing by controlling the influencing factor of humidity to minimize the fishy smell in the final product.

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Chapter 3

Sensory evaluation of Gwamegi using response surface methodology.

Abstract

Sensory evaluation of Gwamegi dried using Response surface methodology was evaluated based on the level of fishy smell, Gwamegi smell, preference, and appearance. Results from the panel were collected based on 3-point hedonic scale. The score of the fishy smell and Gwamegi smell was 1.4 (Weak smell) and 2.1(Medium smell) and Preference and appearance score 1.6(Like) – 2.3 (Neither Like nor Dislike) and 1.6 -2.4 (Medium) respectively. R^2 and the overall mean from the statistical analysis for the fishy smell, Gwamegi smell, preference, and appearance were 0.6983, 0.8385, 0.9636, 0.8181 and 1.85, 1.89, 1.89, 1.98, respectively. There was no significant difference ($p>0.05$) in all sensory quality of all treatments during Gwamegi processing. Moreover, RSM was shown to be an adequate approach for Gwamegi processing with acceptable sensory quality.

Keywords: Gwamegi, RSM, Sensory evaluation

Introduction

In food industry, there are many kinds of odor qualities and for consumer satisfaction, odor problem in food is a serious concern. Specifically, in seafood industry a variety of undesirable odors are associated with handling from capture to table; processing method used for an increase of shelf life, packaging method, the material used and inappropriate storage condition after processing may affect products quality by generating undesirable odors which may influence consumer rejection. Sensory testing is used as a tool for evaluating the goodness or the badness of food. Different sensory attributes are perceived such as appearance, odor, texture, and flavor. Appearance focuses on color, size, shape, and surface texture. Texture mainly shows viscosity and consistency (Meilgaard, et al 2006). However, the odor evaluation is complicated and delicate to evaluate the quality value.

Gwamegi is processed from an oily fish known to be a rich source of the n-3 or omega-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). They are essential to human because the body can't produce it and they have to be provided in diets such as fish or fish oil. The n-3 fatty acids belong to one of two families of polyunsaturated fatty acids (PUFAs), the other being the n-6 (omega-6) family. The n-3 family is derived from the essential fatty acid, alpha-linolenic acid, and the n-6 family from the essential fatty acid, linoleic acid (Mason, 2000). The lipid of fish muscle is susceptible to oxidation in mostly oily fish due to the higher content of unsaturated fatty acids. A compound known to be related to off-odor are formed from enzymatic reaction, lipid oxidation, microbial action and environmentally or thermally derived reaction (Yarnpakdee, et al 2012).

Marine fish tissue contains a chemical known as trimethyl amine oxide which starts to break down after death due to bacteria activity and generates ammonia and trimethyl amine. At caught fish smells fresh and mild with the bacteria activity. Then, the fish starts to smell fishy or ammonia-like bacterial decomposition, volatilization, and chemical reactions during the fish-drying process. Bacterial decomposition of fish and its by-products produces several chemicals with strong odor such as trimethylamine, ammonia, amines, sulfides, mercaptans, and volatile fatty acids such as acetic, propionic, botanic and pentatonic acids. The purpose of this study is to conduct a sensory test to evaluate the smell level in samples dried at different conditions and to discuss the influence of results obtained in Chapter 1 and 2.

Materials and Methods

Determination of sensory quality

Gwamegi samples used in this study were processed in the procedure of Chapter 1 and they were obtained from the drying process based on response surface mythology with an experimental design presented in Table 2. Gwamegi quality assessments by sensory evaluation for 15 samples dried in different conditions were carried out with an involvement of human participants. Hedonic scale method with the 3-point score was used to design a questionnaire to evaluate the level of fishy smell, Gwamegi smell, overall preference in smell and overall appearance. Panelists of 7 undergraduate and graduate students in Pukyong National University were selected for this evaluation and the average scores for each sample were calculated. The scale for smell is present in Table 15. Fishy smell, Gwamegi smell, preference, and appearance were designed as follow (1; weak, 2; Medium, 3; Strong), (1; Like, 2; Neither like nor dislike, 3; Dislike) and (1; Good, 2; Medium, 3; Bad) (Wu & Mao, 2008).

Table 15. Three-point hedonic scale for sensory evaluation in Gwamegi

Scale	Fishy smell	Gwamegi smell	Preference	Appearance
1	Weak	Weak	Like	Bad
2	Medium	Medium	Neither like nor dislike	Medium
3	Strong	Strong	Dislike	Good

Statistical Analysis

Sensory evaluation of the results from the panel of 7 peoples who evaluated smell, preference, and appearance of Gwamegi processed using response surface methodology with a three-factor quadratic model, was analyzed using SAS software by running the RSREG procedure for response evaluation. R-square was obtained to confirm the good fit of the used model used and table of the coefficient of regression was used to make a formula used in Maple 17 to design a 3D graphics for interpreting the effect of independent variable interaction on sensory quality.

Results and Discussion

Sensory evaluation is used and the dependable to assess the quality in the food industry. Human senses are used for this test which makes it easy, quick and effective to get feedback of selectivity of the designed products. In this study, 4 dependent variables such as fishy smell, Gwamegi smell, preference, and appearance were evaluated in 15 different samples of Gwamegi using two types of such senses as smell and sight. Table 16 presents all results from the experiments which are the overall mean of response given by 7 evaluators with the calculated standard deviation. Table 17, 19, 21, and 23 show the results of Statistical analysis of fishy smell, Gwamegi smell, preference and appearance in Gwamegi processing respectively. The below formulas made from Table 18, 20, 22, and 24 were used to generate the 3D graphics for the evaluation of response surface in the 4 dependent variables such as fishy smell, Gwamegi smell, preference, and appearance, respectively.

$f_1 := 1.252083 - 0.105833 * x_1 + 0.187500 * x_2 + 0.047917 * x_3 + 0.001167 * x_1 * x_1 - 0.000625 * x_2 * x_1 - 0.003646 * x_2 * x_2 + 0.000417\ x_3 * x_1 - 0.000521 * x_3 * x_2 - 0.000579 * x_3 * x_3$

$f_2 := -1.528125 - 0.085000 * x_1 + 0.337500 * x_2 + 0.116667 * x_3 + 0.000625 * x_1 * x_1 - 0.000625 *$

$x_2 * x_1 -0.008594* x_2 * x_2 +0.001250* x_3 * x_1 +0* x_3 * x_2 -0.002170* x_3 * x_3$

f_3:=$-1.997917+0.080417* x_1 +0.165625* x_2 +0.034375* x_3 -0.001333* x_1 * x_1 -0.001250* x_2 * x_1 -0.002083* x_2 * x_2 +0.001458* x_3 * x_1 -0.000521* x_3 * x_2 -0.001100* x_3 * x_3$

f_4:=$-1.288542+0.055417* x_1 +0.190625* x_2 +0.005208* x_3 -0.000208* x_1 * x_1 -0.004375* x_2 * x_1 -0.001302* x_2 * x_2 +0.001042 * x_3 * x_1 +0.0001562* x_3 * x_2 -0.000839* x_3 * x_3$

where f_1 = fishy smell, f_2 = Gwamegi smell, f_3 = preference, and f_4 = appearance and x1 = humidity, x2 = drying temperature, and x3 = time.

Table 16. Sensory Evaluation of Gwamegi processed under different conditions

	Uncoded			Response Function			
Treatment	H	T	Tm	Fishy Smell	Gwamegi Smell	Smell Preference	Appearance Preference
1	50±3	22	36	1.9±0.7	2.0±0.6	2.0±0.6	2.0±0.6
2	50±3	14	36	1.9±0.9	2.0±0.6	1.9±0.9	2.0±0.8
3	50±3	18	48	1.9±0.7	2.0±0.6	2.0±0.6	2.1±0.4
4	50±3	18	24	1.6±0.5	1.7±0.8	1.6±0.5	1.7±0.8
5	30±3	22	36	2.0±0.8	2.1±0.7	2.0±0.6	2.4±0.5
6	30±3	14	36	1.9±0.7	2.0±0.0	1.7±0.5	1.7±0.8
7	30±3	18	48	2.1±0.9	1.7±0.5	1.6±0.8	1.9±0.7
8	30±3	18	24	2.0±0.8	2.0±0.6	1.9±0.7	2.0±0.8
9	40±3	22	48	2.0±0.8	1.9±0.7	2.0±0.6	2.3±1.0
10	40±3	22	24	1.6±0.8	1.4±0.5	1.9±0.7	1.6±0.5
11	40±3	14	48	1.9±0.9	1.9±0.7	1.9±0.7	2.1±0.9
12	40±3	14	24	1.4±0.5	1.4±0.5	1.7±0.8	1.7±1.0
13	40±3	18	36	2.0±0.6	2.1±0.4	2.1±0.7	2.1±0.9
14	40±3	18	36	1.9±0.9	2.1±0.7	2.1±0.7	2.0±0.6
15	40±3	18	36	2.0±0.8	2.1±0.7	2.0±0.6	2.1±0.7

The value is averaged ± standard deviation (n=7).
Abbreviation H(humidity), T(temperature), Tm(Time)

Table 17. Statistical analysis of Fishy smell level in Gwamegi processing

Response Surface for Variable Fishy smell	
Response Mean	1.853333
Root MSE	0.186637
R-Square	0.6983
Coefficient of Variation	10.0703

Table 18. Coefficient regression model estimated by the RSREG procedure for fishy smell

Parameter	**DF**	**Estimate**	**Standard Error**	**t Value**	**Pr > |t|**	**Parameter Estimate from Coded Data**
Intercept	1	-2.343750	13.126362	-0.18	0.8653	5.000000
humidity	1	-0.012500	0.333869	-0.04	0.9716	-0.375000
temperature	1	0.843750	0.892350	0.95	0.3878	2.602085E-16
time	1	0.010417	0.243269	0.04	0.9675	0.375000
humidity*humidity	1	-0.001250	0.003491	-0.36	0.7349	-0.125000
temperature*humidity	1	0	0.008385	0.00	1.0000	-1.21431E-16
temperature*temperature	1	-0.023438	0.021819	-1.07	0.3318	-0.375000
time*humidity	1	0.002083	0.002795	0.75	0.4896	0.250000
time*temperature	1	0	0.006988	0.00	1.0000	-1.09288E-16
time*time	1	-0.000868	0.002424	-0.36	0.7349	-0.125000

Table 19. Statistical analysis of Gwamegi Smell in Gwamegi processing

Response Surface for Variable Gwamegi Smell	
Response Mean	1.893333
Root MSE	0.159687
R-Square	0.8385
Coefficient of Variation	8.4342

Table 20. Coefficient regression model estimated by the RSREG procedure for Gwamegi smell

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	-1.528125	3.124699	-0.49	0.6455	2.100000
humidity	1	-0.085000	0.079477	-1.07	0.3337	-0.012500
temperature	1	0.337500	0.212422	1.59	0.1730	0.012500
time	1	0.116667	0.057910	2.01	0.1001	0.125000
humidity*humidity	1	0.000625	0.000831	0.75	0.4859	0.062500
temperature*humidity	1	-0.000625	0.001996	-0.31	0.7668	-0.025000
temperature*temperature	1	-0.008594	0.005194	-1.65	0.1589	-0.137500
time*humidity	1	0.001250	0.000665	1.88	0.1191	0.150000
time*temperature	1	0	0.001663	0.00	1.0000	2.515349E-17
time*time	1	-0.002170	0.000577	-3.76	0.0132	-0.312500

Table 21. Statistical analysis of smell preference in Gwamegi

Response Surface for Variable Smell Preference	
Response Mean	1.893333
Root MSE	0.053229
R-Square	0.9636
Coefficient of Variation	2.8114

Table 22. Coefficient regression model estimated by the RSREG procedure for Gwamegi preference

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	-1.997917	1.041566	-1.92	0.1132	2.066667
humidity	1	0.080417	0.026492	3.04	0.0289	0.037500
temperature	1	0.165625	0.070807	2.34	0.0665	0.087500
time	1	0.034375	0.019303	1.78	0.1351	0.050000
humidity*humidity	1	-0.001333	0.000277	-4.81	0.0048	-0.133333
temperature*humidity	1	-0.001250	0.000665	-1.88	0.1191	-0.050000
temperature*temperature	1	-0.002083	0.001731	-1.20	0.2827	-0.033333
time*humidity	1	0.001458	0.000222	6.58	0.0012	0.175000
time*temperature	1	-0.000521	0.000554	-0.94	0.3907	-0.025000
time*time	1	-0.001100	0.000192	-5.72	0.0023	-0.158333

Table 23. Statistical analysis of appearance in Gwamegi processing

Response Surface for Variable Appearance	
Response Mean	1.980000
Root MSE	0.162275
R-Square	0.8181
Coefficient of Variation	8.1957

Table 24. Coefficient regression model estimated by the RSREG procedure for appearance

Parameter	DF	Estimate	Standard Error	t Value	Pr > |t|	Parameter Estimate from Coded Data
Intercept	1	-1.288542	3.175346	-0.41	0.7017	2.066667
humidity	1	0.055417	0.080765	0.69	0.5231	-0.025000
temperature	1	0.190625	0.215865	0.88	0.4176	0.100000
time	1	0.005208	0.058848	0.09	0.9329	0.175000
humidity*humidity	1	-0.000208	0.000845	-0.25	0.8150	-0.020833
temperature*humidity	1	-0.004375	0.002028	-2.16	0.0835	-0.175000
temperature*temperature	1	-0.001302	0.005278	-0.25	0.8150	-0.020833
time*humidity	1	0.001042	0.000676	1.54	0.1840	0.125000
time*temperature	1	0.001562	0.001690	0.92	0.3977	0.075000
time*time	1	-0.000839	0.000586	-1.43	0.2119	-0.120833

Fishy smell

The fishy smell from all 15 treatments was scored between 1.4 (Weak smell) and 2.1(Medium smell) as presented in Table 16. The sample recorded with week fishy smell was dried at a drying temperature of 14°C, humidity of 40% for a duration of 24 hrs, while samples dried between 36-48 hrs, humidity of 40-50% and drying temperature of 18-22°C showed an increase in fishy smell rated medium level. Statistical results are shown in Table 17. With R-square of 0.6983, the total mean of smell score was 1.85 close to medium fishy smell. There was no significant difference ($p>0.05$) in the fishy smell of all treatments during Gwamegi processing. Figure 6-A made from the f_1 equation, expressing drying time and temperature effects at the initial drying time and temperature, shows that fishy smell was weak, but the fishy smell was increasing as they were increasing. In Figure 6-B at an initial time with the increased humidity of 45-50%, the smell was weak, but on the other side at the initial humidity with the increased drying time, the fishy smell was increasing. In Figure6-C fishy smell increased as drying time increased at the lowest humidity, while with the increased humidity at its initial stage the fishy smell was low and remained constant at a humidity of 40-45. The increase in drying time and temperature caused more increase of the fishy smell than that of humidity. In other to reduce the fishy smell, humidity, drying time and temperature should be 40-50%, 24 hrs, and 14°C, respectively.

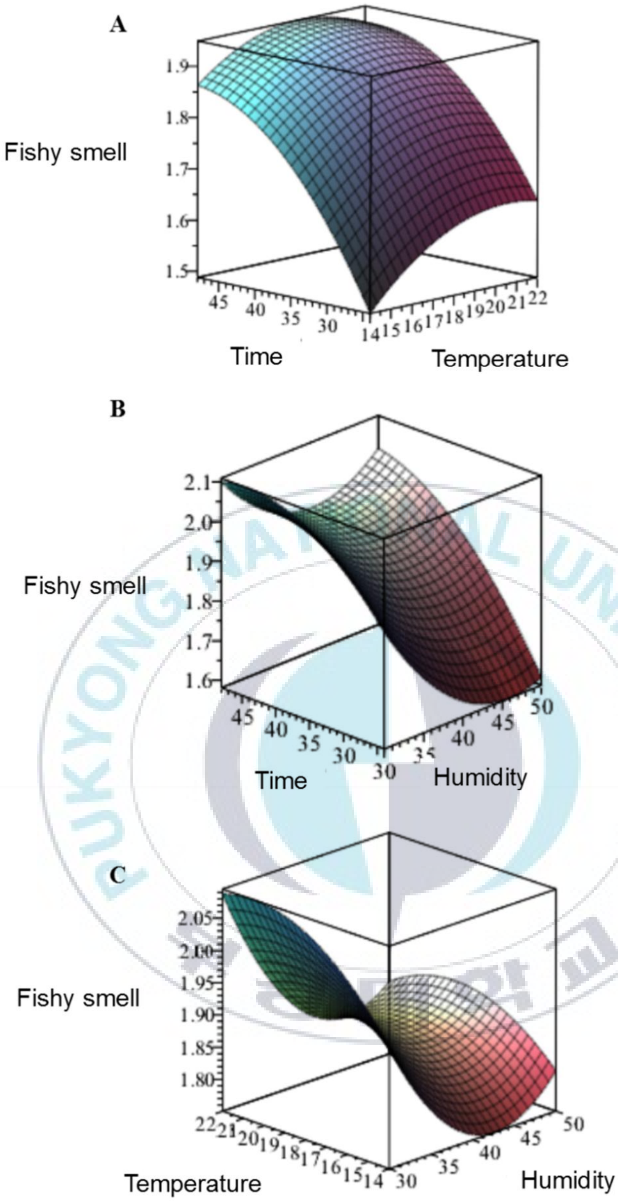

Figure 6. Three-dimensional response surface plots showing interactive (A) time and temperature, (B) time and humidity and (C) temperature and humidity on Fishy smell in Gwamegi processing.

Gwamegi smell

Gwamegi smell score in Gwamegi processed from the 15 conditions of Table 16 was 1.4 (weak) for the sample dried at the humidity of 40%, 22-14°C drying temperature for 24 hrs and 2.1 (medium) for the sample dried at a humidity of 30%, drying temperature of 18-22°C for 36 hrs. Table 19 presents statistical analysis results such as R-square and overall mean, respectively as following 0.8385 and 1.89. There was no significant difference ($p>0.05$) in Gwamegi smell of all treatments during Gwamegi processing. Figure 7 was made to show the effect of drying condition on Gwamegi smell. Figure 7-A shows that in the drying condition of the initial drying time and temperature with the fixed humidity at 40%, the smell was a week and in the condition of drying time of 35 hrs and drying temperature of 18°C, the Gwamegi smell was at its maximum. Further increase in both conditions induced the reduction of the Gwamegi smell. Figure 7-B expresses the effect of drying time and humidity at the fixed temperature at 18°C on the smell. Initially, the smell was low, but at 35-40 hrs and at the humidity of 40%, the Gwamegi smell was at its highest value further. Effect of drying temperature and humidity at the fixed time at 36 hrs is shown in Figure 7-C. The increase of Gwameli smell has been influenced by the increases in drying time and temperature than the increase in humidity. To reduce the Gwamegi smell, humidity, drying temperature and time should be 35-45%, 14-18°C, and 24-36 hrs, respectively.

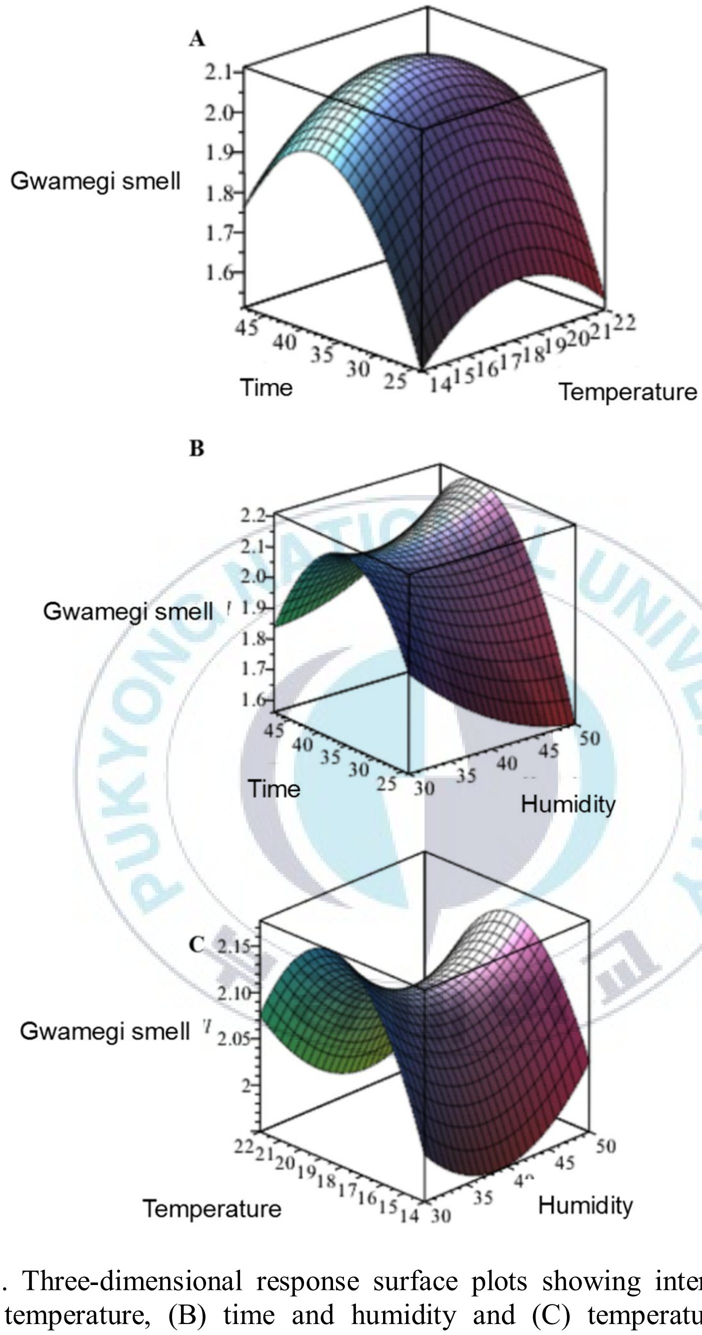

Figure 7. Three-dimensional response surface plots showing interactive (A) time and temperature, (B) time and humidity and (C) temperature and humidity on Gwamegi smell in Gwamegi processing.

Preference

The evaluation of preference was based on the smell which was influenced by the balance of both previously evaluated smell. Preference was between 1.6 (like) – 2.3 (Neither like nor dislike) for the samples dried under humidities of 30-50%, drying temperatures of 14-18°C for duration of 24–36 hrs, respectively. Its results are displayed in Table 16. Statistical results of R-square and mean value in Table 21 are 0.9636 and 1.89, respectively. There was no significant difference ($p>0.05$) in preference of all treatments during Gwamegi processing, but the interaction of cross product between drying time and humidity showed a significant difference ($p<0.05$) influenced by the significant difference observed on humidity factor. Figure 8 drawn from the above f_3 formula shows different drying condition and its influence on the overall preference. The higher the preference the lower the smell and the lower the preference the higher the smell. An interaction between drying time and temperature at the fixed humidity at 40% shows that with an increase in both drying time and temperature the preference was decreased, which means the smell value was to be higher, but at the initial drying time and temperature the preference was high (Figure 8-A). The interaction between drying time and humidity at the fixed drying temperature at 18°C is shown in Figure 8-B. The preference was increased as both drying time and humidity increased. Figure 8-C shows the effect of temperature and humidity at the fixed time of 36 hrs. As the drying temperature was increased, its preference was lower than the increased effect of humidity. Figure 8 interprets the preference results as being influenced by the results of both fishy and Gwamegi smells. The increases in drying time and temperature had a negative effect on Gwamegi preference than that of humidity.

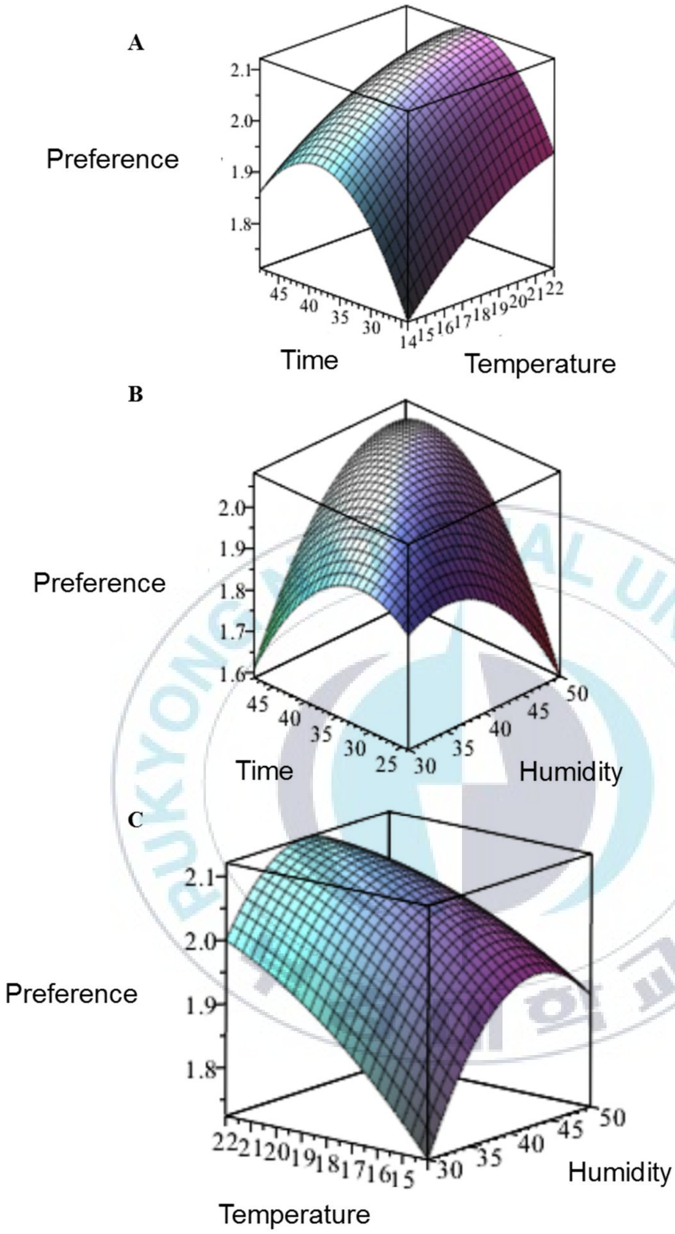

Figure 8. Three-dimensional response surface plots showing interactive (A) time and temperature, (B) time and humidity and (C) temperature and humidity on preference in Gwamegi processing.

Appearance

Appearance results in Table 19 are in the range of 1.6 -2.4 (Medium scores) for samples dried at the humidity of 40% and 30%, the drying temperature of 22°C for both score, and the drying time of 24 hrs and 36 hrs, respectively. Statistical results in Table 23 present result with R-square of 0.8181 and overall mean of 1.98. There was no significant difference ($p>0.05$) in the appearance of all treatments during Gwamegi processing. Figure 9 was made from the f_4 formula. Figure 9-A shows the effect on the appearance by drying time and temperature with the fixed humidity at 40%. As drying time and temperature were increasing, appearance score was low, which was mostly influenced by drying time than temperature. The same observation in Figure 9-B was present, but the high influence on the low score in appearance was observed when drying time and humidity were increasing at the fixed temperature of 18°C, which is different in the interaction of drying temperature and humidity. In Figure 9-C as drying temperature and humidity increased with the fixed time at 36 hrs, appearance score increased up to the maximum value where the humidity was 40-45% above. At that time, a decrease in appearance was observed. From Figure 9 drying temperature and humidity elucidate a positive influence in appearance than drying time. At the drying condition of humidity of 30-40% with a high temperature at the fixed time of 36 hrs, Gwamegi with a good appearance can be produced.

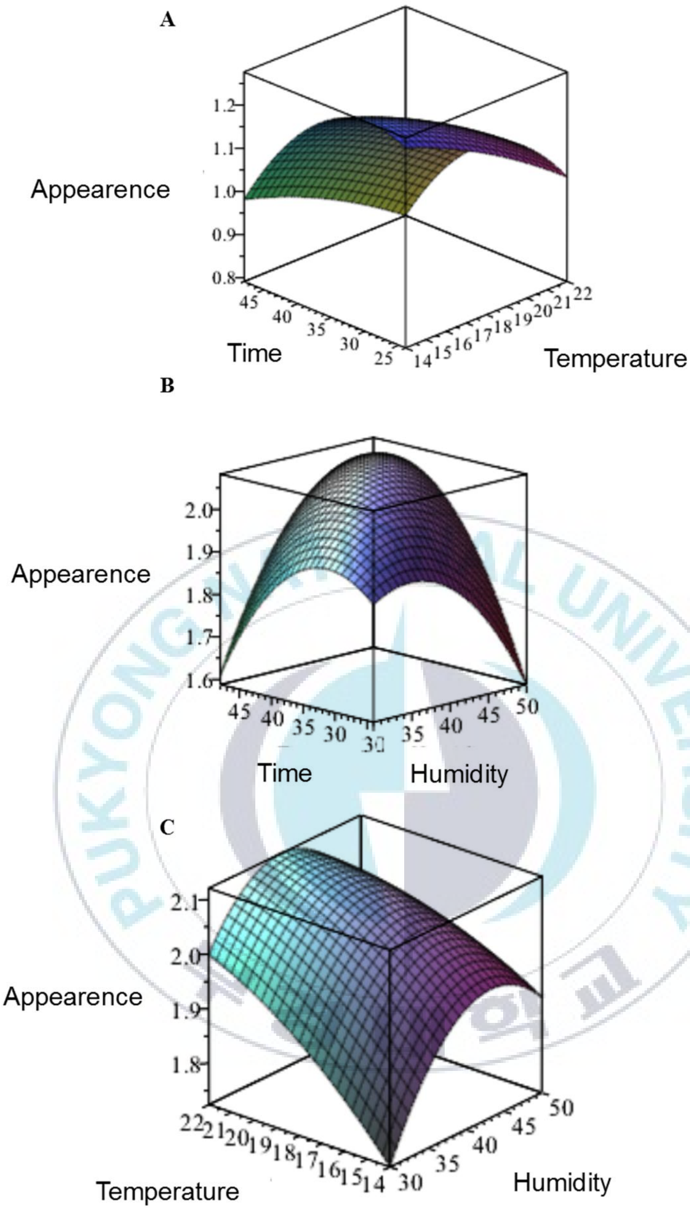

Figure 9. Three-dimensional response surface plots showing interactive (A) time and temperature, (B) time and humidity and (C) temperature and humidity on appearance in Gwamegi processing.

Conclusion

RSM was successfully used to evaluate sensory quality of Gwamegi by identifying the level of fishy smell, Gwamegi smell, preference and appearance for further determination of the best condition to minimize the smell by maximizing sensory quality along with the appearance. For both fishy and Gwamegi smell, increase in drying time and temperature caused an increase of smell than that in humidity. In other to reduce the smell, humidity, drying time and temperature should be 35-45%, 24 hrs, and 14°C, respectively. Besides preference was influenced by the level of both fishy smell and Gwamegi smell as samples with low preference was affected by time and temperature followed by humidity. Considering that the sample with acceptable appearance was made from the condition with a humidity within the range of 30-45% and with increased drying temperature at the fixed time of 36 hrs, RSM should be considered as a good model for Gwamegi processing with good quality. All evaluated quality parameter in this chapter were within the range of medium score explained by the amounts of TVBN and TMA obtained in Chapter 2.

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