Thesis for the Degree of Master of Science

Optimizing recipes of cooked long-grain Jasmine rice with sea-tangle patch (*Laminaria japonica*) and its effect on glycemic index

by

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The Graduate School

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태국 재스민 쌀을 이용한 다시마밥 제조조건의 최적화와 혈당지수에 대한 효과

Advisor: Prof. Hong-Soo Ryu

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Table of Contents

List of Figures

List of Tables

Optimizing recipes of cooked long-grain Jasmine rice with sea-tangle patch (*Laminaria japonica*) and its effect on glycemic index

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Abstract

Thai Jasmine rice (*Oryza sativa,* long grain Indica *var*) is very popular in southeastern Asia and China for non-glutinous fluffy texture and fragrant smell. However it has a higher starch digestibility, which leads to the increased glycemic index (GI). Therefore it may require modifying cooking method for diabetes patients. The objectives of this study were to optimize the ratio of Thai Jasmine rice, sea-tangle patch, and olive oil (CLTR) based on consumers' acceptance. GI of the cooked Thai Jasmine rice (CLR) was measured as a control. Sensory evaluation and response surface methodology were used to determine the optimal ratio. Texture analysis and nutritional evaluation were also performed on the cooked Jasmine rice with sea-tangle patch with optimal recipe. A multiple regression equation was developed in quadratic canonical polynomial models. 26 of trained Chinese panelists in their forties participated.

It was found that color, flavor, adhesiveness and glossiness were correlated highly with overall acceptability. Optimal formulation of CLTR was rice 34.8%, sea-tangle 2.8%, water

61.9% and olive oil 0.5%. CLTR had a lower hardness, but higher springiness and cohesiveness compared to CLR. It did however, had the same adhesiveness and chewiness with CLR ($p<0.01$). The addition of sea-tangle and olive oil delayed retro-gradation of starch in CLTR and also showed the higher level in total dietary fiber, protein and ash contents($p<0.01$). The degree of gelatinization, *in vitro* protein and starch digestibility of CLTR were lower than those of CLR ($p<0.01$). Based on Wolver' method, the GI of CLTR (52.9, Inc) was lower compared with co-energy CLR (70.94, Inc), which demonstrated that CLTR is effective in decreasing and stabilizing blood glucose level owing to its lower degree of gelatinization and starch digestibility($p<0.01$). Results presented that CLTR could contribute in developing a healthier Thai meal for families and fast-food industry.

1. Introduction

Rice is the main food crops and edible grain, and 65 percent of Chinese take rice as the staple food. China is the world's largest rice producer and consumer countries, accounting for more than 30 percent. With reform and opening up and the development of economy recently, the diet and food habits of people seem to be diversified and international. As the animal food consumption grows sustainably, per capita rice consumption has an apparent trend to downward. The per capita rice consumption in China dropped from 85.9 kg in 1991 to 67.6 kg in 2008 (Feng M et al. 2010).

Thai Jasmine rice has been popular in China for a long time for non-glutinous fluffy texture and fragrant smell. Besides, the rice contains high nutritional value, which makes it attract more and more Chinese consumers.

At present China's imports of Thailand rice about 300 thousand tons every year, which a large part of it to southern coastal areas (Guangdong province), particularly the consumption ratio of Thai rice in Hong Kong is more than 70% (China Food Industry 2010 Yearbook).

Nowadays in China, the diet which is based on Western style fast food gradually occupies a significant proportion. High energy and high sugar in those foods not only accounts for the obesity but also may lead to diabetes, coronary heart disease and various types of cancer culprit.

In contrast, the traditional Oriental diet based on grain and plant food seems to be more healthy and balanced. Rice is the main part of Oriental diet. It is becoming more and more important to enhance the nutritional value of white rice and to improve its single taste.

The research mainly focuses on adding some seaweed and olive oil as auxiliary materials when cooking, researching the formula and analyzing the nutritional value of the best formulations according to food nutrition theory and statistical formula.

As the refined white rice lacks dietary fiber, adding some sea-tangle patch can help to solve those problems. The sea-tangle contains alginic acid of 11 to 45%, fiber and mannitol which cannot be digested, and kelp elements (Lee JG et al. 2002). All the elements contained have multiple health care functions, such as regulating blood lipids, lowering blood glucose and blood pressure, and anti-coagulation, anti-tumor, anti-virus, anti-radiation and enhancing immunity. In addition, sea-tangle is rich in protein, vitamins and minerals, especially iodine, calcium, selenium and other ingredients which are beneficial to humans (Choi HG et al. 2003).

It is the traditional custom to add animal cooking fat when cooking Thai Jasmine rice. The measure can improve the taste of rice and make it soft and smooth. However, animal cooking fat contains high level of cholesterol and saturated fatty acids, which are liable to cause many diseases such as cardiovascular, high blood sugar and high cholesterol. Olive oil can be used as alternative to solve those problems.

While some components of the Oriental diet may protect against heart trouble, the higher sodium content of sauces counter that benefit. Many cooks use salt when cooking rice dishes to keep them from boiling over. Try using a dash of olive oil and reducing the heat slightly.

Olive oil can improve the metabolic function of the organism because it has great antioxidant capacity, rich vitamins and highly unsaturated fatty acids. It has a very significant effect in lowering blood glucose, cholesterol, preventing the occurrence of cardiovascular disease, and improving the digestive system function and control obesity (China Agricultural

University, College Of Food Science & Nutritional Engineering, Research Labs, 2011).

The glycemic index (GI) is an index reflecting the rise of blood sugar after eating food. It can be the real reflection of changes in blood glucose caused by the digestion and absorption of food. As for rice containing high-carbohydrate, the index can reflect the influence of food to blood sugar. After the reaching of food with high GI, the food can be digested quickly and absorbed to the blood. The amount of blood sugar can reach the peak in a short time (Wolever TS et al. 1991).

The rice is dominant in blood sugar regulation as a staple food. The rise of the blood sugar can increase the sugar intake of muscle, liver and adipose tissue. It can also inhibit glycogen release of hepatic lipolysis. Taking food of high GI can accelerate the process and lead to the result that fat and sugar are absorbed quickly. The decrease of fat and sugar will lead to reactive hypoglycemia and more free fatty acids. The trend may result hunger sensation in the next lunch. If this trend continues, chronic metabolic disease is slowly emerging.

GI of food is a quantitative value which represents the level the food glycemic effects compared with a standard control food (glucose). It is physiological parameters of the evaluation carbohydrate (Miller J. 1999).

All carbohydrate in the human body is digested and degraded to monosaccharides and they will lead to blood sugar rising and induce the body to produce satiety. The secretion of insulin transfers the blood glucose to ceil in order to restore normal blood glucose levels. The fast reduce of insulin may lead to fast hunger. Therefore, it is the ideal state to keep the blood glucose in a stable level for both normal people and people with diabetes. Eating food with low GI, the blood glucose decline in a very slow speed while in the contrary food with high GI may make the blood glucose easily absorbed by the body. The content of carbohydrate cannot reflect the degree of utilization of food chemically and GI gives a new nutritional evaluation method for food with carbohydrate.

Response surface methodology (RSM) on sensory evaluation was used to optimize cooking condition of long-grain rice containing sea-tangle patch and olive oil (CLTR). By using the RSM, the research can acquire the factors affecting the quality of kelp rice including amount of sea-tangle patch, amount of added water and olive oil. The goal of the present study was to systematically investigate optimal formulation of long-grain rice with high sea-tangle patch content effect of optimizing cooking condition of CLTR on glycemic index, can reflect the blood sugar level after dinner accurately, which can help to control postprandial blood glucose (Ryu HS et al. 2004).

2. Experimental Methodology

2.1 Materials and standard recipe

Thai Jasmine rice was produced by the GOLDEN ELEPHANT FRAGRANT, Tresplain Investments, Ltd., Hong Kong (10kg). Regarding rice preparation, Non-elutriating rice series (vacuumize) was not needed to wash the rice before cooking. Dried sea-tangle patch *(Laminaria japonica)* was manufactured by the GARIPO Sea Food Korea Company (300g). Spanish extra virgin olive oil (Pressured) was purchased from a local supermarket (Namcheon Megamart, Busan city).

Weigh 300g Thai Jasmine rice long-grain rice, → add water, sea-tangle patch and olive oil according to central composite design → steep for 20min → cook using electric cooker under low-pressure conditions.

2.2 Cooked long-grain Jasmine rice (CLR)

Cooked long-grain Jasmine rice was prepared using electric cooker (atm 0.9~1.0 kg/cm^2, CUCKOO ELECTRONICS CO, LTD. KOREA)

2.3 Cooked long-grain Jasmine rice containing sea-tangle patch and olive oil (CLTR)

Cooked long-grain Jasmine rice with sea-tangle patch and olive oil mixture was prepared using electric cooker. The mixture ration of CLR containing sea-tangle and water, olive oil were according to Table 1 and Table 2 of the central composite design (atm 0.9~1.0 kg/cm^2, CUCKOO ELECTRONICS CO, LTD. KOREA).

2.4 Experiment plan for response surface methodology (RSM)

A response surface design was used to study the relative contribution of different variables to rice quality and to determine optimum formulations of CLTR content.

The objectives of this study were to optimize the mixture ratio of CLTR containing sea-tangle and olive oil and compare CLTR to CLR on taste and nutrient value (Ryu HS et al. 2004).

2.4.1 Central composite design for RSM

Response surface methodology (RSM) was used in this trial to study the simultaneous effects of three compositional variables, namely: sea-tangle patch (0–24g), water (420–450g) and olive oil (0–8g) (Table 1). The three factors were expressed using X_1, X_2 and X_3 respectively. Effects of independent variables: [X_1] amount of sea-tangle patch, [X_2] amount of added water, [X_3] amount of added olive oil (Ryu HS et al. 2004).

Five levels of each factor or variable (sea-tangle patch, water and olive oil content) were provided in accordance with the principles of the central composite design. For the statistical analysis, the five levels of the three variables were coded as -2, -1, 0, 1, 2.

As well as interactions among them on quality of CLTR were studied by RSM.

The arguments were coded according to the equation $x_i = (X_i - X_0)/\Delta X$. In the equation, x_i was the coded value of the independent variable, X_i was the true value of the independent variable, X_0 was the true value of the experimental center point from variable, ΔX was the step change of the variable and the average score of Sensory evaluation Y was the response value. The relation between code variable levels(x_1) and true value(X_1):

$x_1 = (X_1 - 4)/2$ $x_2 = (X_2 - 480)/30$ $x_3 = (X_3 - 4)/2$

2.4.2 Sensory evaluation

In this study, Minitab 16 statistical software was used to design and analyze and the number of the formulations in the optimizing design is 16 as shown in Table 2.

Table 1. Independent variables and their levels for central composite design.

Independent variables	*Symbol	Code variable levels				
		-2	-1	0	1	2
Sea-tangle patch (g)	X_1	0	6	12	18	24
Water(g)	X_2	420	450	480	510	540
Olive oil(g)	X_3	0	2	4	6	8

* [X_1] Amount of sea-tangle patch, [X_2] amount of added water, [X_3] amount of added olive oil.

Table 2. Arrangement of the three-variable, five-level response surface design

Exp. No	Variable levels			Exp. No	Variable levels		
	X_1	X_2	X_3		X_1	X_2	X_3
1	-1	-1	-1	***9***	-2	1	0
2	1	1	1	***10***	1	1	-2
3	0	0	0	***11***	-1	0	-1
4	2	0	0	***12***	0	-2	0
5	0	2	0	***13***	1	-1	-1
6	0	0	2	***14***	1	-1	1
7	1	1	0	***15***	0	0	-2
8	2	2	1	***16***	1	1	-1

* [X_1] Amount of sea-tangle patch, [X_2] amount of added water, [X_3] amount of added olive oil.

26 Chinese panelists about 40 years old are divided averagely into two teams and they will receive the sensory evaluation separately. Scoring form was used to record the results. Sensory scores: Very Good (9), Good (7), General (5), Bad (3), Worst (1). With 9-hedonic scale of questionnaire test on color, glossiness, flavor, adhesiveness, overall acceptability. The 26 panelists come from different professional personage of all kinds of social classes. They will receive sense evaluation education to grasp the methods to evaluate food before they begin the last evaluation. They will firstly evaluate the smell of rice when it is hot, and then watch the color and shape of the rice. At last, they will evaluate the taste by chewing the rice. Clean drinking water was provided when they evaluate the rice. They have to rinse the mouse using the clean water when they begin to evaluate another sample (Wu W et al. 2009). At last, the scores will be summarized and the average score will be calculated according to the scores of the testers.

*Response surface methodology on sensory evaluation was used to optimize cooking condition of long-grain rice containing sea-tangle patch (CLTR).

2.5 Textural analysis

The optimum formulations of CLTR and CLR content were cooked using a rice cooker (Cuckoo pressure jar cooker, low-pressure 0.9~1.0 kg/cm^2, Korea). Texture of cooked rice was measured with a Texture Analyzer (model TA-XT2, Stable Microsystems, England) using the compression test (5). 1 g of cooked rice was then arranged in a single-grain layer on the base plate. A compression plate was set at 5 mm above the base. A two-cycle compression, force versus distance program was used to allow the plate to travel 4.9 mm, return and repeat. The test speed was 1 mm/ sec. A cylindrical plunger of 50 mm diameter was employed. Parameters were hardness (height of the force peak on the first cycle), adhesiveness, cohesiveness, springiness and gumminess (Sawidtree P et al. 2011).

2.6 Statistical Analysis

Find out optimizing cooking condition of CLTR from contour and response surface plots of overall acceptability and then use statistical analysis software: Minitab16, to analyze the results of sensory evaluation. Multivariate analysis software, SPSS version 11.5, significance differences between means were detected by the Duncan's multiple range test ($p<0.05$), (Ryu HS et al. 2004).

The results will be measured by the variance analysis and effectiveness. Duncan's multiple range tests will be used to detect the effectiveness of those projects which have effective values. IAUC can be calculated using geometric method and the GI of the other two kinds of tester can be calculated on the basis of the fact that the IAUC of glucose is 100% (Wolever TS et al. 1991).

2.7 Proximate composition

The proximate compositions of the all samples were determined using the following AOAC procedure (AOAC 1990). Moisture of the sample was determined after drying at 105ºC to attain constant weight. Crude protein was calculated by multiplying the nitrogen of the samples with the factor of 6.25 by the semi-micro Kjeldahl method (Gerhardt Vapodest 30). Crude lipid (Soxhlet extraction), ash (gravimetric) were determined by employing AOAC methods (1990).

The percentage of carbohydrate can be acquired by minus the percentages of moisture, crude protein, crude lipid and ash from the sample. The percentage of total dietary fiber (TDF) can be measured using the Proskey method (Proskey L. 2003).

2.8 *In vitro* protein digestibility

The *in vitro* protein digestibility values of all the samples were determined by the method of Oduro (2011) with modification by the AOAC method (AOAC 1982), the procedure used 4 enzyme method tried the different method for protein digestibility using three proteolytic enzymes. They determined the correlation coefficient between two assays and it showed high correlation (R^2=0.9955), (Oduro FA et al. 2011).

The α-chymotrypsin (Sigma 38 units/mg solid), trypsin (Sigma 13,390 BAEE units/mg solid) and protease (*Streptomyces griceus*, Sigma 46 units/mg solid) were used in three enzyme method, The reference protein used was ANRC casein. Digestibility was calculated as follows:

% Digestibility (three enzyme) = 234.84 – 22.56 x. Where x is the pH of sample at 20 minutes.

% Digestibility (four enzyme) = 1.03 x (three enzyme digestibility) – 0.34

2.9 *In vitro* starch digestibility

The *in vitro* starch digestibility was determined using the freeze dried CLTR and CLR samples (50 mg/ml of 0.2 M phosphate buffer, pH 6.9) after amylolysis with 0.5 ml of pancreatic amylase (500,000 U/mg) suspension (0.44 mg/ml of 0.2 M phosphate buffer, pH 6.9) at 37°C for 2h according to the method of Alonso R et al. (2000). At the end of the incubation period, 4 ml of 3, 5-dinitrosalicylic acid reagent were added and the mixture boiled for 5 min. After cooling, the absorbance of the filtered solution was measured at 550 nm with maltose used as standard. *In vitro* starch digestibility was expressed as percentage (Ordonez Ramos LR et al. 2012).

2.10 Gelatinization degree

The starch gelatinization degrees can be measured by malt diastase of Yamasita method (Yamasita TR. 1968).

2.11 Glycemic Index

This study was conducted using internationally recognized GI methodology. Glycemic index has been confirmed its excellent function to prevent chronic diseases since 1990s (Wolever TS et al. 1991).

Subject fasted overnight at the experimental unit before each study day. 8~12 subjects in each group were assigned in random order. The test meal was evaluated by measured blood glucose during 2 hours in the group subjects. The carbohydrate content of CLTR and CLR, equivalent to 50g glucose for each meal, was calculated by proximate composition (Table 9). 50g glucose was the control food in this study. GI of test meal was calculated by Wolever method (1991).

To minimize day to day variation of glucose tolerance, the reference food was tested in triplicate in each subject. Ten healthy subjects aged between 20-30 years were recruited. All test and reference foods were served with 200 ml of water. Each subject was asked to consume 50 g of available carbohydrate portions of test foods and reference food. Finger capillary blood samples were collected at the start of eating and 15, 30, 45, 60, 90 and 120 min after consumption. A glucose meter (ACCU-CHEK

Active, Germany) was used to collect finger capillary blood samples (1~2 μl, ACCU-CHEK Active Test Strips). Each group tests each sample every three days (Yuan CS et al. 2011).

The CLTR compared with co-energy CLR, glucose, to discuss if CLTR have good effect to decrease and stable blood glucose.

Test food GI= (Test food IAUC/ Reference food IAUC) *100%

(Incremental area under the curve, IAUC)

Glucose GI (reference food) =1

3. Results

3.1 Sensory evaluation

Response surface regression model can be built to optimize the response factor levels through the Minitab 16 data processing. Based on the 16 CLTR formulations according to the central composite design, the average score of sensory evaluation can be considered as the response value, as shown in Table 3. The 16 formulations by central composite design using quadratic canonical polynomial model (Ryu HS et al. 2004).

The experimental data in Table 3 will be processed using quadratic regression fitting and tested by lack-of-fit test and significance tests of regression coefficients of the mathematical model for predicting sensory score of CLTR with different formulas. The experimental data will be processed based on polynomial regression analysis using sensory evaluation as the response. The analysis can figure out the polynomial equation model, as shown in Table 4.

Table 3. Central composite design arrangement and responses by Chinese forties

Exp. No	Variable levels			Response				
	X_1	X_2	X_3	Y_1	Y_2	Y_3	Y_4	Y_5
1	-1	-1	-1	5.9	5.5	5.6	5.7	5.5
2	1	1	1	6.3	6.5	6.1	6.3	6.3
3	0	0	0	6.3	6.1	6.3	6.3	6.3
4	2	0	0	6.3	6.5	6.1	6.5	6.3
5	0	2	0	6.3	6.3	6.2	6.1	6.3
6	0	0	2	5.6	6.1	6.2	6.8	6.1
7	1	1	0	6.3	6.6	6.7	6.4	6.5
8	2	2	1	6.7	6.7	6.3	6.3	6.6
9	-2	1	0	5.7	5.5	5.5	5.5	5.5
10	1	1	-2	6.0	5.3	5.7	5.5	5.7
11	-1	0	-1	5.8	5.5	5.6	5.7	5.7
12	0	-2	0	5.8	5.8	5.6	5.4	5.6
13	1	-1	-1	6.3	5.6	5.4	6.1	5.6
14	1	-1	1	5.5	6.1	5.6	6.3	6.0
15	0	0	-2	5.8	5.3	4.8	5.5	5.6
16	1	1	-1	6.3	6.0	6.4	6.1	6.3

* Y_1= color, Y_2= flavor (taste), Y_3= adhesiveness, Y_4= glossiness,
Y_5= overall acceptability.

**Sensory scores: Very Good (9), Good (7), General (5), Bad (3), Worst (1)

Table 4. RSM program-derived polynomial equation by the Chinese forties.

Response	Polynomial equation	R^2*	P-value
Color	$Y_1=6.20023+0.121278X_1+0.128806X_2-0.0323188X_3-0.0322618X_1^2-0.0504185X_2^2-0.129866X_3^2+0.0841034X_1X_2-0.148500X_1X_3+0.194482X_2X_3$	0.145	<0.0001
Flavor(taste)	$Y_2=6.21582+0.222595X_1+0.131179X_2+0.222967X_3-0.0693511X_1^2-0.0626062X_2^2-0.158877X_3^2+0.0407235X_1X_2+0.0266489X_1X_3+0.0161843X_2X_3$	0.247	<0.0001
Adhesiveness	$Y_3=6.42480-0.0392729X_1+0.0990203X_2+0.327116X_3-0.0765767X_1^2-0.130916X_2^2-0.244639X_3^2+0.316246X_1X_2-0.276848X_1X_3-0.103374X_2X_3$	0.182	<0.0001
Glossiness	$Y_4=6.35270+0.185858X_1+0.0817159X_2+0.278088X_3-0.0827866X_1^2-0.143861X_2^2-0.0643000X_3^2+0.00687099X_1X_2-0.0976856X_1X_3+0.107268X_2X_3$	0.184	<0.0001
Overall acceptability	$Y_5=6.22305+0.159217X_1+0.171543X_2+0.142363X_3-0.0817015X_1^2-0.0657478X_2^2-0.120945X_3^2+0.0725306X_1X_2+0.00228563X_1X_3-0.0173305X_2X_3$	0.187	<0.0001

*Coefficient of determination

As shown in Table 4, the F value of the response of the five projects: color, flavor (taste), adhesiveness, glossiness, overall acceptability is 64.21. The data means that the height of the model is obvious. The value of P is less than 0.0001 and the data means that the factor level of the model is obvious in the mass. The R^2 (coefficient of determination) value is between 0.145 and 0.247. The data means that the experimental method is reliable and the level range of each factor is reasonable enough to estimate the sensory evaluation of samples (Ryu HS et al. 2004).

The overall acceptability sensory evaluation of the panelists can be analyzed by SAS and the output of ANOVA table is shown in Table 5.

The experimental data could be processed using Minitab 16 and the data graph could be drawn using statistical analysis software. The best recipe of CLTR could be analyzed using response surface methodology including contour plot and response surface plot. The graphic of response surface analysis (RSM) is a specific response Y and the corresponding arguments make up a three-dimensional diagram. The diagram may reflect the influences of arguments to response variables. Figure 1 and 2 intuitively reflected the impact of various factors on the response value. The condition in which the extrema exists should be at the center of the circle according to the contour map.

The response surface chart shows the impact on the sensory evaluation score of the interaction of sea-tangle patch and water, the sea-tangle patch and olive oil, and water and olive oil. As can be seen, the sensory score all of the five items (attribute) increases with the increased amount of the sea-tangle patch. When the amount of sea-tangle patch reaches the maximum score, the score will also reach a maximum, which is in sympathy with the sea-tangle patch.

Figure 1 show the contour map of the overall acceptability of the response variables when the addition amount of sea-tangle patch is held to 6g, 12g and 18g.

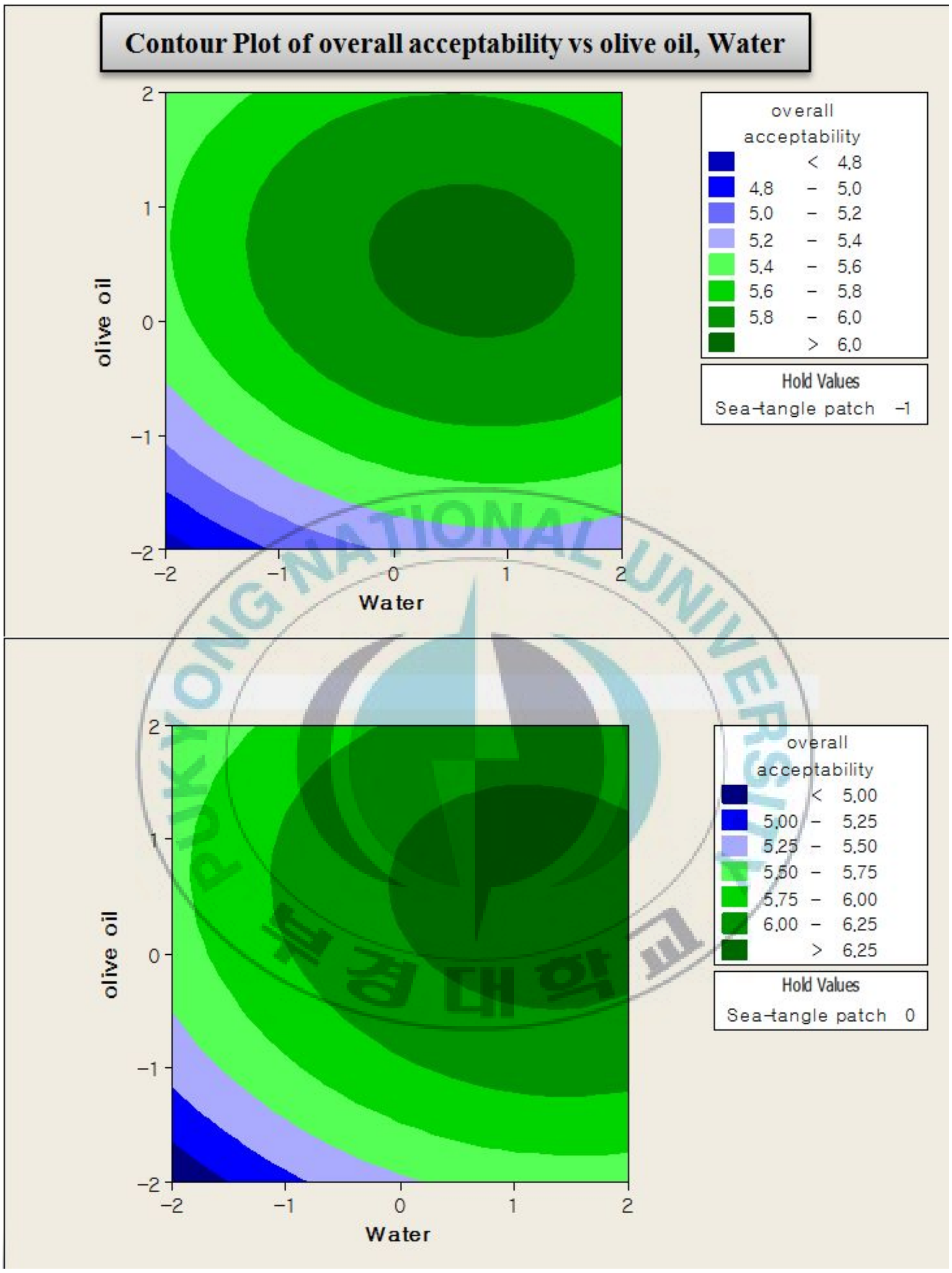
Table 5. SAS output of ANOVA table for overall acceptability by the forties.

Response Surface for Variable overall Acceptability

Response Mean	5.993750
Root MSE	0.119384
R-Square	0.9616
Coefficient of Variation	1.9918

Regression	DF	Type I Sum of Squares	R-Square	F Value	Pr > F
Linear	3	1.765429	0.7919	41.29	0.0002
Quadratic	3	0.297150	0.1333	6.95	0.0223
Crossproduct	3	0.081281	0.0365	1.90	0.2306
Total Model	9	2.143860	0.9616	16.71	0.0014

Residual	DF	Sum of Squares	Mean Square	F Value	Pr > F
Lack of Fit	6	0.085515	0.014252	.	.
Pure Error	0	0	.		
Total Error	6	0.085515	0.014252		


Contour Plot of overall acceptability vs olive oil, Water
olive oil
Water
overall acceptability
< 4.8
4.8 – 5.0
5.0 – 5.2
5.2 – 5.4
5.4 – 5.6
5.6 – 5.8
5.8 – 6.0
> 6.0
Hold Values
Sea-tangle patch -1
olive oil
Water
overall acceptability
< 5.00
5.00 – 5.25
5.25 – 5.50
5.50 – 5.75
5.75 – 6.00
6.00 – 6.25
> 6.25
Hold Values
Sea-tangle patch 0

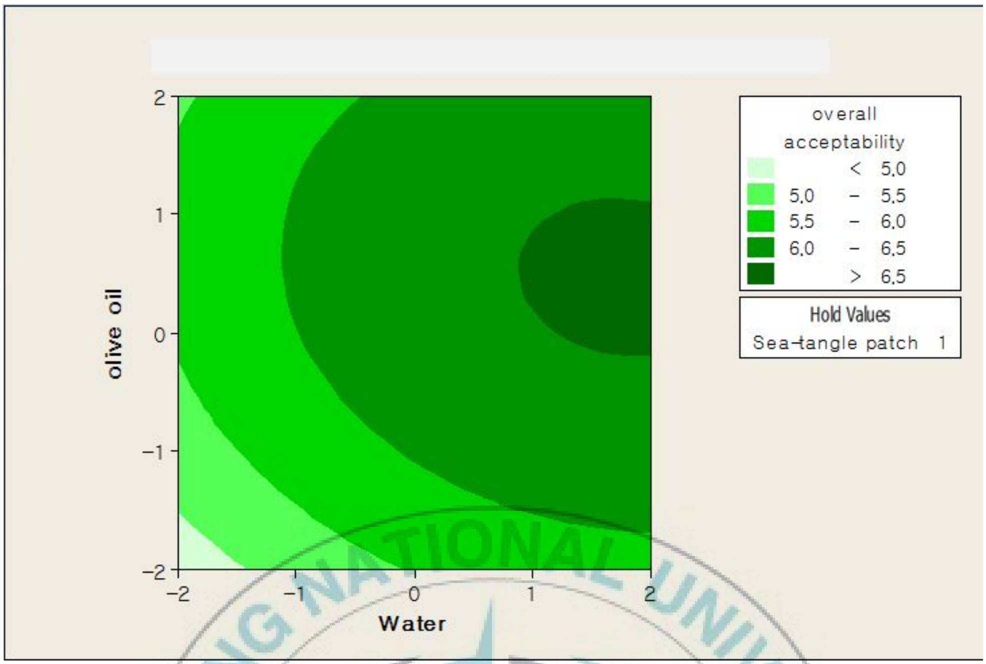


Fig. 1. Contour plots of overall acceptability by the forties.

Figure 1 reflects the fact that there is no exclusion of subjects for the taste and texture of the sea-tangle and the acceptance is quite high.

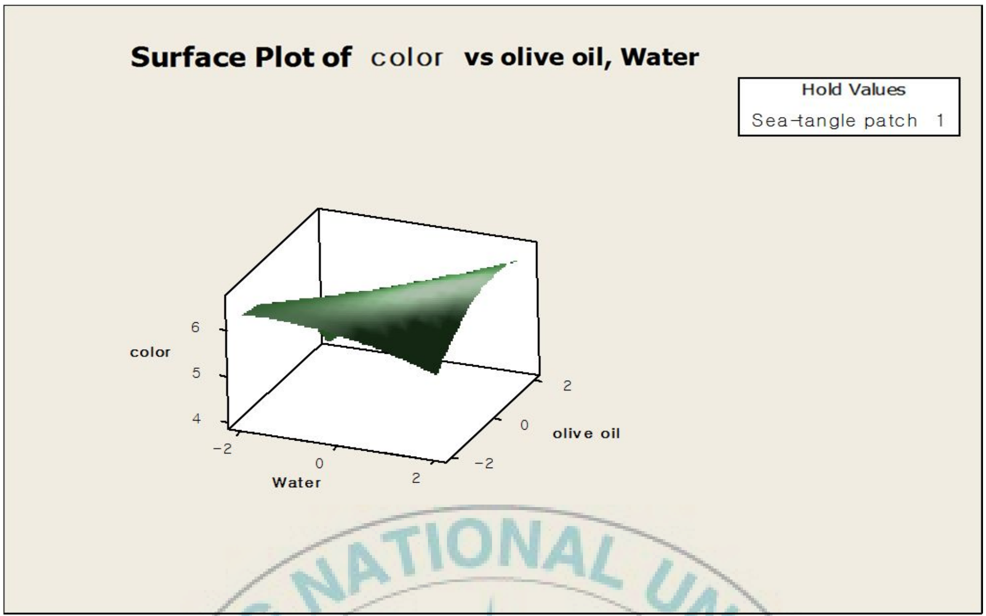
The average age of the 26 panelists is about 40 years old and these middle-aged people pay more attention to health because diabetes and cardiovascular disease will break out more easily. Besides, these panelists have more knowledge on nutrition and they know the fact that sea-tangle includes high dietary fiber, as well as a variety of bioactive substances which are good for health. Therefore they have more sea-tangle in daily life. Based on the facts, the sensory evaluation may include some subjective factors, which may lead to the result that the score will be higher with the increased addition of kelp.

The study also includes a sensory evaluation aiming at about 20 college students who age at over 20 years old. The diet of such young people is more biased Western-style and they are fond of fast food and fried food. The meat-based diet exists far and wide, and the acceptance of botanical dietary food is relatively low.

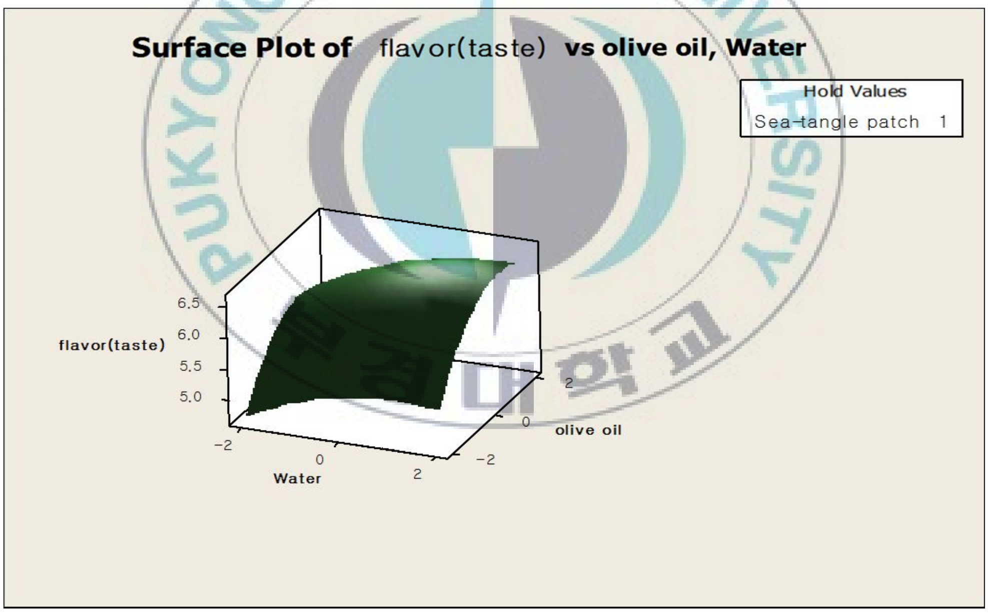
The test results show that the score of the five projects of sensory evaluation on young people age about 20 years old declines with the addition of sea-tangle patch. The highest average score belongs to the rice without sea-tangle patch. It will get more praise if olive oil is added.

The 20-year-old main subjects basically cannot accept the taste of sea-tangle patch and they have a strong exclusion of it. As the result of sensory evaluation is not in sympathy with the goal of the study, no more discuss and analysis will be carried out in such condition.

Figure 2 shows the response surface plot of the five project response when the addition of sea-tangle patch is held to 18g (X_1=1).

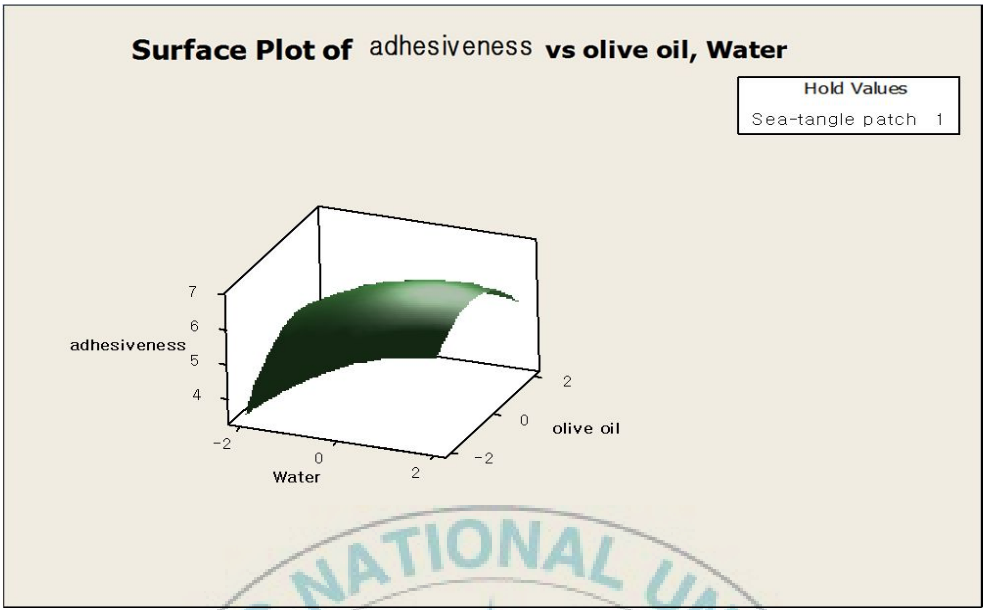


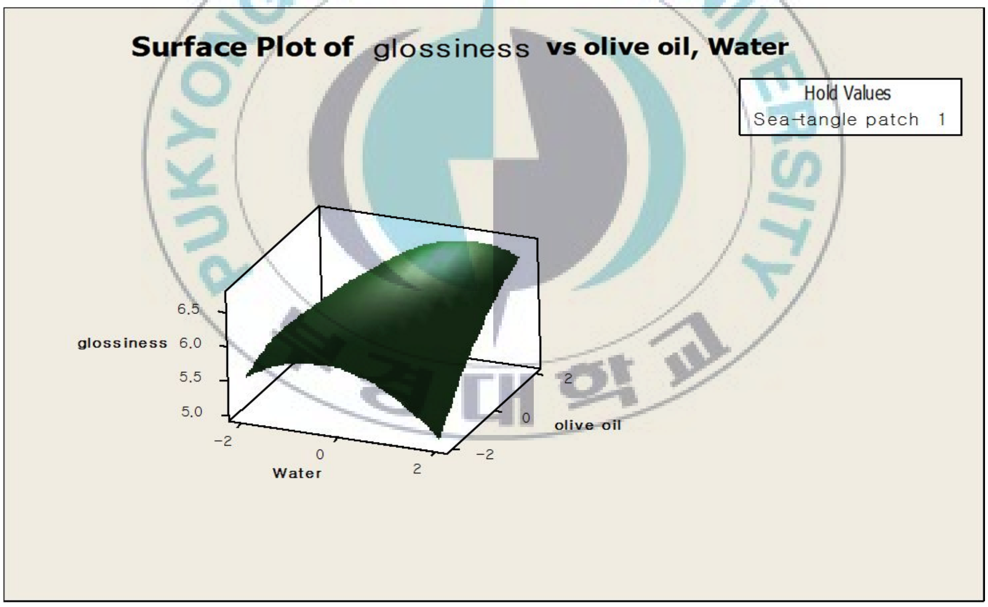
Surface Plot of color vs olive oil, Water
Hold Values
Sea-tangle patch 1
color
6
5
4
-2
0
2
Water
2
0
-2
olive oil



Surface Plot of flavor(taste) vs olive oil, Water
Hold Values
Sea-tangle patch 1
flavor(taste)
6.5
6.0
5.5
5.0
-2
0
2
Water
2
0
-2
olive oil

(Continued)


Surface Plot of adhesiveness vs olive oil, Water
Hold Values
Sea-tangle patch 1
adhesiveness
7
6
5
4
-2
0
Water
2
olive oil
2
0
-2


Surface Plot of glossiness vs olive oil, Water
Hold Values
Sea-tangle patch 1
glossiness
6.5
6.0
5.5
5.0
-2
0
Water
2
olive oil
2
0
-2

(Continued)

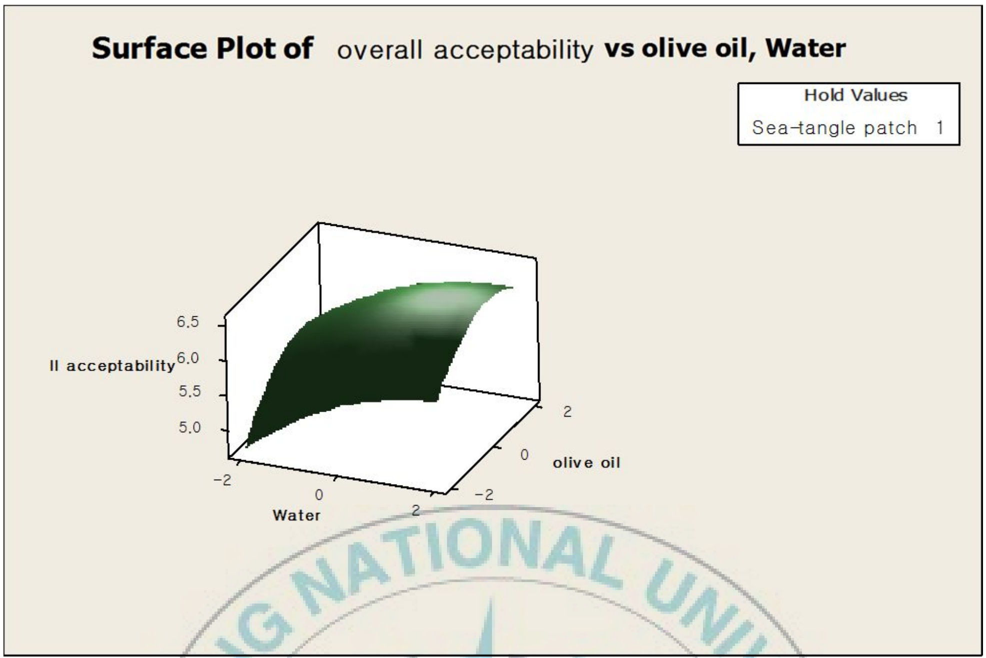


Fig 2. Response surface plots of 5 response variables by the twenties (X_1=1)

We found that color, flavor, adhesiveness and glossiness were correlated highly with overall acceptability.

According to the response surface plot of sensory score, the peak appears when the addition of the sea-tangle patch was the most when the addition of water and olive oil were constrained to some certain extent.

The best recipe of CLTR could be figured out using Minitab response optimizer assuming the goal of sensory score is 8 points. At the same time, the sensory evaluation of the response of the five projects: color, flavor (taste), adhesiveness, glossiness, overall acceptability can be optimized. The maximum point of the comprehensive response surface map, also called the optimal level of the three main factors, could be figured out by regression equation derivation and set the response surface map to zero. The respective goal, purposed, on-line, weight and importance of the five projects is shown in Table 6 (Cao XF et al. 2009).

The result of the analysis of Minitab response optimizer is shown in Figure 3.

Table 6. Response value optimization settings

Response	Off-line	Purposed	On-line	Weight	Importance
Color	1	8	9	1	1
Flavor (taste)	1	8	9	1	1
Adhesiveness	1	8	9	1	1
Glossiness	1	8	9	1	1
Overall acceptability	1	8	9	1	1

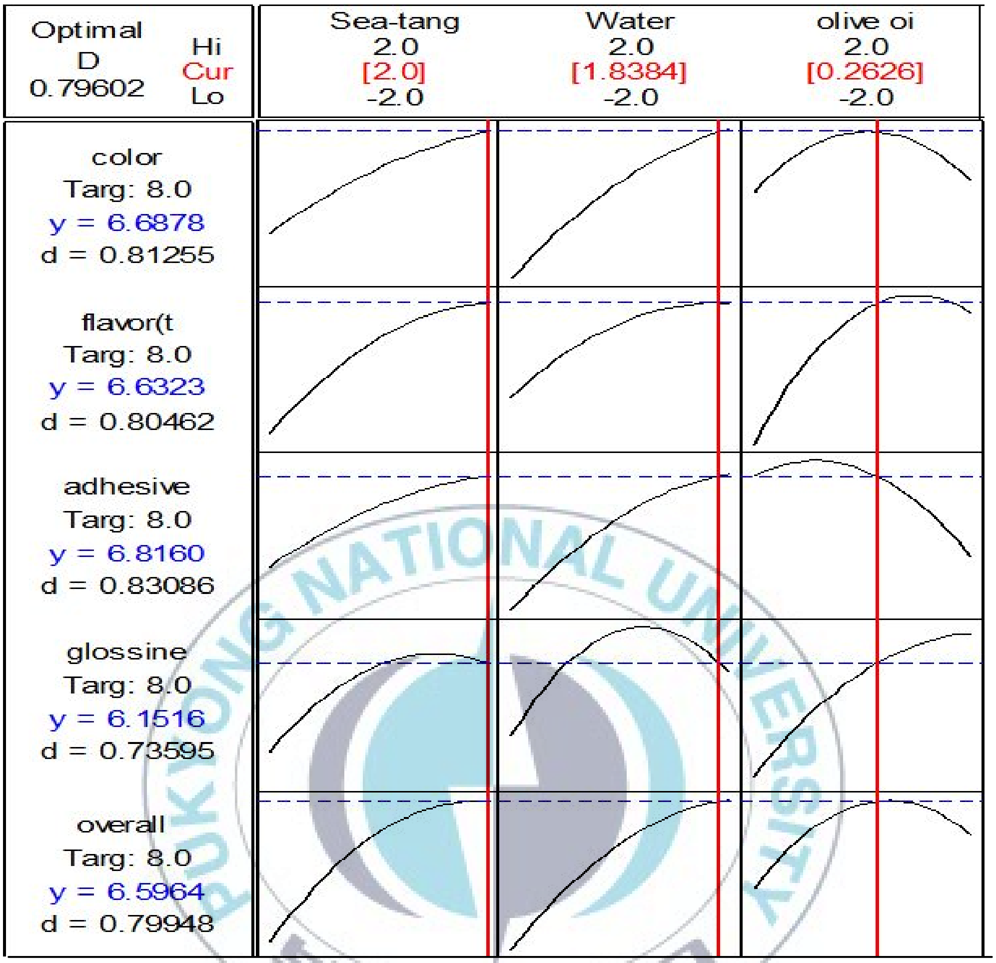


Fig. 3. Response optimization curves of five attributes

*When X_1 = 2 ; X_2=1.8384 ; X_3=0.2628, the maximum of the forecast available sensory evaluation score is 0.79602.

So we know that the optimal formulation of CLTR was rice 34.8%, sea-tangle 2.8%, water 61.9% and olive oil 0.5%.

According to the analysis of the Minitab response optimizer, the best recipe of CLTR was that the addition amount of sea-tangle patch was the maximum of the target scope while the addition amount of water and olive oil are in a horizontal scope, which is consistent with experimental targets.

Early in the study, the experiment always uses Central Composite Design to study the key impacting indicator of the best recipe of CLTR and determine the horizontal range of the optimum amount on the basis of preliminary experiments and analysis of references.

Considering the cooking tools of CLTR may be the general household rice cooker and 300g rice is usually set as the standard, the amount of the addition of the sea-tangle patch should be determined based on the facts. In preliminary experiments, every time when the amount of the addition of sea-tangle patch reaches or exceeds 30g, then overall appearance of the rice will become worse and it will cause great impact on the quality and appetite of CLTR. Taken all these limits of processing into consideration, the amount of the addition of sea-tangle patch is set at 24g.

3.2 Nutritional evaluation

The research established a quadratic mathematical model on the key factors that affect the quality of CLTR using RSM. Significant test of the model is made using statistical methods and the best recipe of producing CLTR was determined: only when rice accounts for 34.8%, sea-tangle 2.8%, water 61.9% and oil 0.5%, can CLTR win the best appraisal.

To detect the textural analysis and nutritional quality of optimizing recipes of CLTR, rice was cooked without sea-tangle and olive oil in the same condition as a comparison (Ryu HS et al. 2004). The textural analysis of CLTR using optimizing recipes is shown as Table 7.

- **Texture profile**

CLTR had a lower hardness, but higher springiness and cohesiveness compared to CLR. It did however, had the same adhesiveness and chewiness with CLR ($p<0.01$)

- **proximate composition**

The proximate composition of dried sea-tangle patch and optimizing recipes of CLTR and CLR in the research is shown in Table 8.

Table 7. **Texture profile analysis of cooked Thai Jasmine rice, long grain Indica *var* (CLR) and CLR containing grainy sea-tangle patch (CLTR).**					
Sample	Hard-ness(kg)	Adhesive-ness(g/sec)	Springi-ness(mm)	Cohesive-ness	Chewi-ness
CLR	17.19[a*]	440[ab]	0.44[b]	0.39[c]	8.13[a]
CLTR	11.27[a]	433[b]	0.61[a]	0.46[b]	7.51[b]

* Mean in the same column with different superscripts are significantly different.

Table 8. Proximate composition and total dietary fiber content of sea-tangle, CLR and CLTR: % (dry basis)

Sample	Moisture	Protein	Lipid	Ash	Carbohydrate	Total dietary fiber
Sea-tangle patch	7.35± 0.38	10.16± 0.2 (10.97)	0.53± 0.23 (0.57)	30.78± 0.54 (33.22)	51.18 (55.24)	40.20± 0.35 (43.39)
CLR	61.71± 0.50	3.17± 0.01 (8.28)	0.56± 0.01 (1.47)	0.19± 0.2 (0.50)	34.37 (89.75)	0.31± 0.16 (0.801)
CLTR	60.31± 0.25	3.47± 0.73 (8.74)	1.15± 0.11 (2.91)	1.19± 0.23 (3.0)	33.88 (85.35)	1.61± 0.28 (4.05)

*Significantly different compare CLR with CLTR ($p<0.05$).

CLR : Cooked long-grain Jasmine rice. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker.

CLTR : Cooked rice long-grain Jasmine rice with sea-tangle patch and olive oil mixture. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker

From the table, the content of total dietary fiber in dried sea-tangle patch is quite large, therefore the optimizing recipes of CLTR (2.8%) with dried sea-tangle patch contains more dietary fiber than CLR and it has some health effects. Besides, the content of protein and ash is also higher than those in CLR.

- **protein and starch digestibility**

In vitro protein and starch digestibility and gelatinization degree of CLTR and CLR are shown in Table 9.

The protein digestibility of CLTR was lower than that of CLR because the added sea-tangle patch had some viscous soluble dietary fiber which would restrain the protease and less digestion and absorption rate of gastrointestinal.

The starch digestibility and gelatinization degree in CLTR were also lower because the dietary fiber and the kelp hormone active substances in CLTR could restrain the effects of α-amylase. Likewise, the physical state, such as the size, the temperature and time in the process of cooking will be influenced because of the added olive oil. In the condition, the degree of gelatinization would be reduced.

Table 9. ***In vitro*** **protein and starch digestibility, and gelatinization degree of CLR and CLTR (%)**

Sample	*In vitro* protein digestibility (%)	*In vitro* starch digestibility (%)	Gelatinization degree (%)
ANRC casein	90.00	-	-
CLR	84.03	18.88	96.4 ± 1.1^{a}
CLTR	80.33	17.51	87.7 ± 3.7^{b}

* **CLR:** Cooked long-grain Jasmine rice. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker.

CLTR: Cooked rice long-grain Jasmine rice with sea-tangle patch and olive oil mixture. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker.

- **Postprandial glucose responses of CLTR and CLR**

CLTR , CLR and reference food (glucose) were tested in 50g available carbohydrate portions. The calculation of 50g carbohydrate in CLTR and CLR refer to contains of carbohydrate in Table 8 (Yuan CS et al. 2011).

The formula is; Test food quality = 100*50/CHO (Test food%).

From the calculation, when the tester ate 148g CLTR, 145g CLR and 50g glucose, the glucose responses diverse in different time. The blood glucose levels rose greatly in the first 30 minutes when testers ate CLR and glucose and then they will decline substantially. However, the blood glucose levels of testers who ate CLTR become smooth after 30 minutes and the rate of decline was quite slow.

The highest value of blood glucose of testers who ate CLTR was 7.4 mmol/L, and the number is 10.1 mmol/L for testers who ate CLR, while the highest value of blood glucose of testers who ate glucose was 10.9 mmol/L. It is obvious that the blood glucose level of testers who ate CLTR was lower than those who eat CLR and glucose. The glucose responses of the influences of CLTR, CLR and glucose are shown in Figure 4.

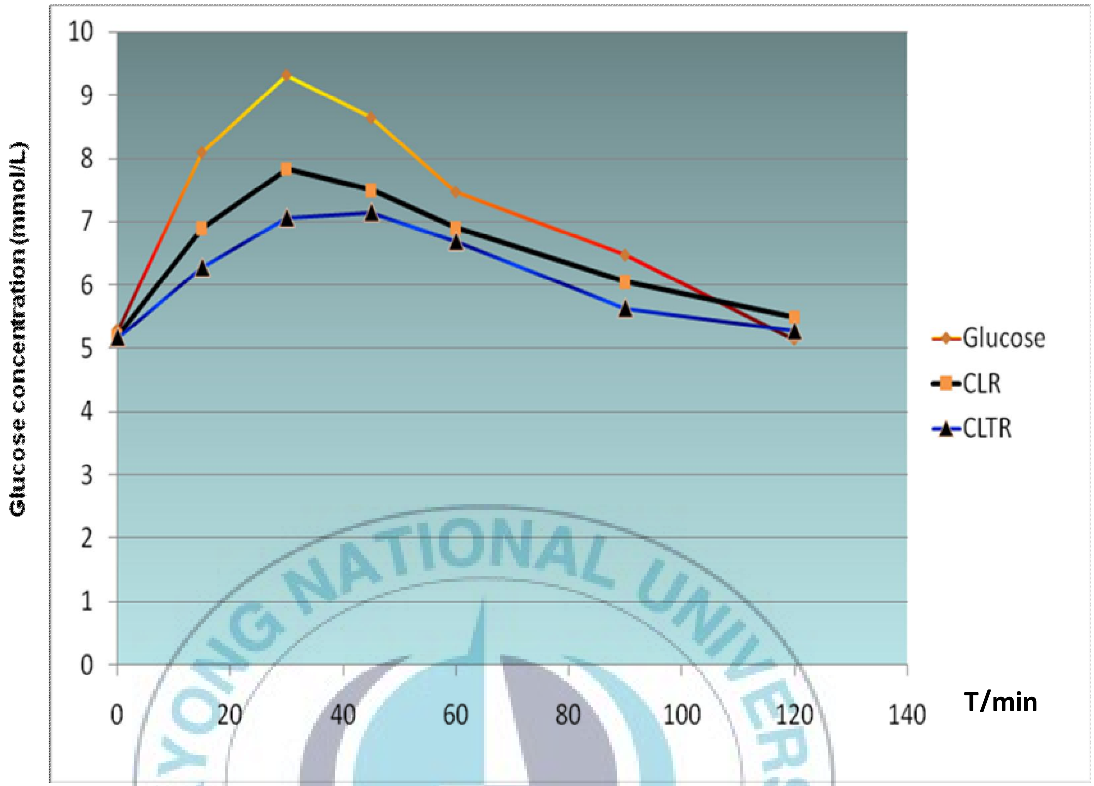


Fig 4. Mean glucose concentrations elicited by glucose, CLR and CLTR in healthy subjects.

*Data are expressed as the change in plasma glucose concentration from the fasting baseline concentration

**The quantities of foods to be measured were computed based on an equivalent content of 50 g carbohydrates . By using 50 g glucose as a reference, each 10 volunteers as one group were measured for fasting blood glucose , and then the levels of blood glucose at various time spots within 2 h after consumption of a specified experimental food.

- **Influences of CLTR and CLR on GI**

The testers were required to eat 148g CLTR, 145g CLR and 50g glucose and the incremental area under the curve (IAUC) would be tested in 2 hours to figure out the glycemic index. Taken the GI of glucose as 100%, compare the glycemic index of CLTR and CLR. The IACU and GI of glucose and CLR was obviously higher than CLTR and the difference makes sense ($p<0.01$). When the CLTR was eaten, the rise of blood glucose was lower than the normal diet. The influences of CLTR, CLR and glucose on GI are shown in Table 10.

Several methods have been used to calculate the area under the glycemic-response curve. Given the same blood glucose data, different methods may result in markedly different areas and GI values (Figure 5). The GI is based on the area under the blood glucose-response curve above the baseline only (Wolever TMS and Jenkins DJA. 1986).

The GI of CLTR (52.9, Inc) was lower compared with co-energy CLR (70.94, Inc), which demonstrated that CLTR was effective in decreasing and stabilizing blood glucose level owing to its lower degree of gelatinization and starch digestibility($p<0.01$).

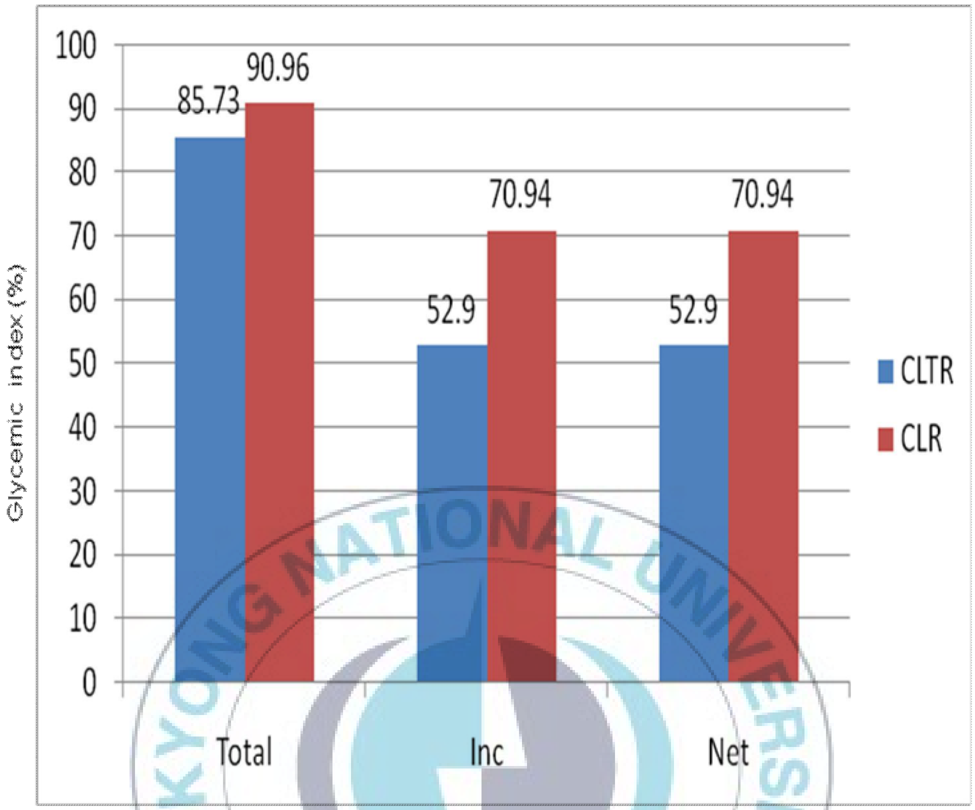
Table 10. The influences of CLTR, CLR and glucose on GI (glycemic index).

Sample	Incremental area under the curve	GI (%)	P
CLR	792.19±43.89*	91.08±2.23*	<0.01
CLTR	746.81±43.89	85.85±2.44	<0.01
Glucose	870.56±58.64	100	—

*Significantly different compare CLR with CLTR ($p<0.05$).

CLR: Cooked long-grain Jasmine rice. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker.

CLTR: Cooked rice long-grain Jasmine rice with sea-tangle patch and olive oil mixture. Pressure cooked at atm (0.9~1.0 kg/cm^2) with electric cooker



*Inc, incremental area under the glycemic-response curve, ignoring the area below fasting, as used for calculating the GI; Net, incremental area under the glycemic-response curve subtracting the area beneath the fasting amount;

Total, total area under the glycemic-response curve ;

Figure 5. Effect of different methods of calculating the area under the curve from the same blood glucose data on the GI of the CLTR and CLR.

The GI of CLTR was obviously lower than glucose and CLR and the glucose response level was also lower. Besides, the natural quality of CLTR was also lower than CLR considering the primary nutrients digestive. Therefore, as the staple of regular diet of modern citizens, CLTR did not only own better eating quality, it could also decline the postprandial glucose levels, which will help to solve the problems caused by the diseases of obesity.

4. Conclusion and Discussion

Thai Jasmine rice has a higher starch digestibility, which leads to the increased glycemic index (GI). Therefore it may require modifying cooking method for diabetes patients.

This research mainly focuses on adding sea-tangle and olive oil as auxiliary materials when cooking, researching the formula and analyzing the nutritional value of the best formulations according to food nutrition theory and statistical formula.

Optimal formulation of CLTR was rice 34.8%, sea-tangle 2.8%, water 61.9% and olive oil 0.5%. CLTR had a lower hardness, but higher springiness and cohesiveness compared to CLR. It did however, had the same adhesiveness and chewiness with CLR ($p<0.01$). The addition of sea-tangle and olive oil delayed retro-gradation of starch in CLTR and also showed the higher level in total dietary fiber, protein and ash contents($p<0.01$). The degree of gelatinization, *in vitro* protein and starch digestibility of CLTR, were lower than those of CLR ($p<0.01$). Based on Wolver' method, the GI of CLTR (52.9,Inc) was lower compared with co-energy CLR (70.94,Inc), which demonstrated that CLTR is effective in decreasing and stabilizing blood glucose level owing to its lower degree of gelatinization and starch digestibility.

The GI of CLTR is obviously lower than glucose and CLR and the glucose response level is also lower. Besides, the natural quality of CLTR is also lower than CLR considering the primary nutrients digestive.

Therefore, as the staple of regular diet of modern citizens, CLTR does not only own better eating quality, it can also decline the postprandial glucose levels, which will help to solve the problems caused by the diseases of obesity.

The 20 years' research indicates that the glucose response of food with starch in the body has high degree of consistency with the digestion rate of carbohydrate outside the body when the content of starch is similar (Englyst HN. 1996; Araya H. 2002). In this condition, people can use starch hydrolysis process outside the body based on enzyme to predict the glucose response of food with starch in the body (Jennifer MG and TJ. 1985).

From *in vitro* starch digestion, the CLR were high GI foods with calculated GI was 91. Generally, Jasmine rice that was completely gelatinized gave the highest GI values because gelatinization, in the absence of retro-gradation or structural changes, starch gelatinization enhances starch digestibility (Khongsak S and AS. 2010).

GI reflects the overall digestion and utilization condition of food consolidating food component and the content, the type and structure of carbohydrate, physical condition and the fabrication process. Instead, these factors can also produce significantly effects on GI (CG. 2000).

CLTR with some ingredients exhibited different pasting properties because of significant effects of processing and possibly the type of ingredients, and differences in their hydration/swelling behaviors.

The physical state of rice, such as the size, the temperature and time in the process of cooking will be influenced because of the abundant fiber in CLTR and the added olive oil. In the condition, the degree of gelatinization will be reduced and the same with GI of food.

As the research of Barclay and Petocz (Barclay AW and Petocz P.2008) indicates, ingestion of food with low GI will reduce the risk of suffering diabetes, coronary heart disease, breast cancer and some other chronic diseases. In the research, food with low GI has less influence on blood glucose and it plays an active role in putting an end to the vicious cycle.

The Instant noodles, with many years of development in China have become common consumer goods. But the type and quantity of instant rice are fewer, still in development.

If the research of long-grain rice (Thai white rice) containing sea-tangle patch can become Instant rice for Chinese market, just like CJ **hetbahn**. Compared with common long-grain rice, CLTR can improve organoleptic quality and Functional. And most importantly, the effect on glycemic index.

Results presented that CLTR could contribute in developing a healthier Thai meal for families and fast-food industry. Maybe will replace instant noodles and be widely welcomed in southern China and have a great economy benefit.

5. References

Alonso R, Aguirre A and Marzo F. (2000). "Effects of extrusion and traditional processing methods on antinutrients and in vitro digestibility of protein and starch in faba and kidney beans." Food Chemistry 68(2): 159-165.

AOAC (1982). "Calculated protein efficiency ratio (C-PER and DC-PER)." Official first action.J.AOAC: 65,496-499.

AOAC (1990). "Official Methods of Analysis." Association of Official Analytical: Washington DC.

Araya H, Contreras P, Alviña M, Vera G and Pak N. (2002). "Comparison between an in vitro method to determine carbohydrate digestion rate and the glycemic response in young men." European journal of clinical nutrition 56: 735-739.

Barclay AW and Petocz P. (2008). "Glycemic index , glycemic load, and chronic disease risk: a meta analysis of observational studies." Am J Clin Nutr 87: 627-637.

Cao XF, Gao YS, Zhao D, Lin J, Xie JL and Xu XS. (2009). "Optimization of process of Mozzarella cheese with soy milk by Response Surface Methodology." China Dairy Industry 2009 Vol. 37 No. 6 pp. 24-27. ISSN1001-2230

Bilidaeris CG. (2000). "The structure and interactions of starch with food constituents." Can J Physiol Pharmacol 69: 60-78.

Choi HG, Jang BH, Rhee JD, Yu BK and Yong CS. (2003). "The effect of Laminarica japonica diet on the pharmacokinetics of glipizide in rats." J Kor Pharm Sci(33): 113-120.

Englyst HN, Veenstra J and Hudson GJ. (1996). "Measurement of rapidly available glucose (RAG) in plant foods: a potential in vitro predictor of glycemic response." British Journal o f Nutrition 75: 327-337.

Feng M, Lu Q and Lin JZ. (2010). "Elastic analysis of urban and rural consumption of rice." Northwest A&F university: 712100.

Jennifer MG and Ian TJ. (1985). "Rates of starch hydrolysis and changes in viscosity in a range of common foods subject to simulated digestion in vitro." Journal of Science of Food and Agriculture 36: 614-620.

Khongsak S and Peter AS. (2010). "Functional properties and starch digestibility of instant Jasmine rice porridges." Carbohydrate Polymers: 82 (2010) 2952–2957.

Lee JG, Lim YS, Joo DS and Jeong IH. (2002). "Effects of diet with sea tangle on calcium absorption, serum composition and feces in rats." J Korean Fish Soc 35: 601-607.

Miller J and Wolever TM. (1999). "Glucose Revolution- The Glycemic Index." New York Marlowe Company: 34-39.

Oduro FA, Ryu HS, Choi ND. (2011). "Effects of cooking conditions on the protein quality of chub Mackerel, *Scomber japonicus*." Fish Aquat Sci.: 14(14), 11-19, 2011.

Ordonez Ramos LR, Choi ND, Ryu HS. (2012). "Effects of processing conditions on the protein quality of fried Anchovy kamaboko *Engraulis japonica*." Fish Aquat Sci 15(4), 265-273, 2012.

Proskey L. (2003). "What is dietary." AOAC Inter: 83(84):985-987.

Ryu HS, Lee JH, Shin ES, Kim MS, Park HY and You BJ. (2004). "Optimizing mixture ratio of mungbean pancake using response surface methodology". 2004 IFT Annual

Ryu HS, Shin ES, Lee JH, Park KT and Jang DH. (2004). "Optimizing cooking condition of short grain rice containing sea-tangle patch." J Korean Soc Food Sci Nutr: 33(10),1726~1734.

Sawidtree P, Sirirat C and Prisana S. (2011). "The Jasmine rice (KDML 105 Variety) adulteration detection using physico-chemical Properties." Chiang Mai J. Sci. : 38(31) : 105-115.

Wolever TMS and Jenkins DJA. (1986). "The use of the glycemic index in predicting the blood glucose response to mixed meals." Am J Clin Nutr 1986 43(167-72).

Wolever TS, Jenkins DJ, Jenkins AL and Josse RG. (1991). "The glycemic index: methodology and clinical implications." The American Journal of Clinical Nutrition: 54:846-854.

Wu W, Liu CM, Li T, Liu W, Wan J and Xu YJ. (2009). "Preparation of nutritional rice fortified with dietary fiber." Food Science 2009, Vol. 30, No. 20.

Yuan CS, Zhang WQ, Zhao XJ, Wang L and Meng J. (2011)."Measurement of glycemic index for whole-grain and coarse cereal foods in Shanxi." Chinese Remedies & Clinics April 2011,Vol.11,No.4.

Yamasita TR. (1968). "Determination of α-starch." Cookery Science Japanese(1): 24-26.