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Optimization of roasting conditions for Thai chili seasoning

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Abstract

The present work aimed to obtain the optimum mixing ratio and roasting conditions for Thai roasted chili seasoning. Different ratios of dried ingredients to soybean oil (2:1, 1.5:1, 1:1, and 1:2 (w/w)) were investigated. The conditions for roasting were optimized using response surface methodology (RSM). A central composite design (CCD) was applied to determine the effects of roasting temperature (80-120 °C) and roasting time (10-30 min) on the physicochemical properties and sensory liking score. The generated model showed a linear and quadratic fit with experimental data. The coefficient of determination (R^2) for all properties and sensory qualities was >0.75. The optimum ratio between dried ingredients and oil was 2:1 (w/w). Based on the RSM overlay plot, the optimal roasting conditions with a maximum sensory acceptability score were a temperature in the range of 89-93 °C and a time of 21-24 min. The point at 91 °C and 23 min was selected for model verification.

Keywords: *chili; optimization; response surface methodology; roasting condition; seasoning.*

1. Introduction

Dried chili and chili powder are spices used as flavorings or condiments and are prepared from ripe chili (*Capsicum* spp.). Their color is provided by carotenoids and its pungency is provided by capsaicinoids, which are considered bioactive compounds due to their beneficial effect on health (Howard, Talcott, Brenes, & Villalon, 2000). They have long been consumed as common seasonings in Thai cuisine. On average, Thai per capita weekly consumption of all chili types and products converted into fresh weight is 218 g (30% as fresh, 43% in dry and powder forms, and the remaining 27% in processed forms). The estimate for dry and powdered chili is 4.87 kg/year (Mustafa, Ali, Satapornvorasak, & Dissataporn, 2006).

Thai roasted chili seasoning is typically made of dry chili, garlic, shallot and oil, but different processes and materials are used in its preparation. Presently, Thai roasted chili seasoning is consumed with noodles to enhance hotness and aroma. This product is not only popular in Thailand but also widely consumed in East and Southeast Asia (Hye-Ryun, Sanjeev, Il-Doo, & In-Joo, 2016). Despite its broad popularity, there is little relevant research on Thai roasted chili seasoning. Most producers lack the necessary knowledge about production conditions and food safety to prevent contamination by foreign matter, fungi, and their toxins (Hiraga, Mahakanjanakul, Sathonsaovapark, & Sittipod, 2004). It is common to stir spices as they are roasted to ensure even heating, and roasting is often done in a drying pan or a special roaster. Roasting usually causes caramelization or Maillard browning of the surface of food, which is considered by some as flavor enhancement (Fernando, Amaratunga, Priyadarshana, 2014). Seasonings are typically roasted until they reach a rather dark color. Pongsawatmanit, Chaethong, Suzuki and Miyawaki. (2013) reported that when roasting in a hot air oven at different temperatures (100-140 °C) for 10 min, color parameters (L^* (lightness), a^* (redness), and b^*(yellowness)) of chili powder decreased with increasing severity of the roasting process. Chaethong and Pongsawatmanit (2015) reported that the application of sodium metabisulfite ($Na_2S_2O_5$) and citric acid in soaking solutions after the blanching process could enhance the quality of dried chili by retarding the color changes and enhancing the residual bioactive compounds. Response surface methodology (RSM) is a useful optimization technique based on multivariate statistics, which includes experimental design and statistical modeling (Yolmeh & Jafari, 2017). RSM could be used to optimize the conditions for preparing Thai roasted chili seasoning.

2. Objectives

The purpose of this study was to optimize mixing ratio and roasting temperature and time for Thai roasted chili seasoning. Selected physicochemical properties such as moisture content, water activity, color and sensory acceptability of the products were evaluated.

3. Materials and methods

3.1 Materials

Sound, red pods of fresh chili (*Capsicum annuum* L.) of the Jinda cultivar, shallot, and garlic were obtained from a wholesale market in Patumthani province and kept at 4 ± 2 °C.

3.2 Preparation of ingredients

The dried chili pod preparation was modified from the method of Chaethong and Pongsawatmanit (2015) by blanching fresh chili at 100 °C for 3 min prior to soaking in 0.25% $Na_2S_2O_5$ and 1.0% citric acid and drying at 65 °C for 14 hr. Then, dried chilies without stems were coarsely ground to obtain chili powder. Fried shallot and garlic were prepared by peeling, washing, slicing to 0.1 cm, mixing with 10% soybean oil (w/w), and drying at 65 °C for 7 hr. The prepared ingredients were analyzed for moisture content, water activity (a_w), and color.

3.3 Experimental design

Prepared dried chilies without stems (5 kg), fried shallot (1 kg) and fried garlic (1 kg) were coarsely ground and mixed with the ratio 5:1:1 to use as dried ingredients. The optimal mixing ratio between dried ingredients and soybean oil (2:1, 1.5:1, 1:1, and 1:2 (w/w)) was studied using a completely randomized design (CRD). The samples were analyzed for moisture content, a_w, and color. Sensory evaluation in attributes of appearance, color, oil content, odor, and overall liking with a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely) by 50 untrained panels was used to select the optimal formulation.

The roasting temperatures and times were selected according to a central composite design (CCD). The independent variables, temperature (X_1) and time (X_2), varied from 80 °C to 120 °C and from 10 min to 30 min, respectively. A hot air oven (Memmert UM500, Federal Republic of Germany) was used for roasting. These ranges in roasting temperature and time reflect the ranges commonly used in conventional seasoning roasting. Each independent variable had three levels: –1, 0, and +1. Thirteen combinations were randomly chosen according to a CCD configuration for the two independent variables using the Design-Expert software (Trial Version 8.0.5.2, Stat-Ease Inc., Minneapolis, MN, USA). The central point of the design was repeated five times with a total of thirteen treatments (Table 1). In the analysis of variance, a measure of the experimental errors was obtained from the replicated points at the center (Peryam, & Pilgrim, 1957).

Table 1 The central composite experimental design for the roasting conditions of Thai roasted chili seasoning.

Experimental Number	Temperature (°C, X_1)		Time (min, X_2)	
	Coded	Actual	Coded	Actual
1	+1	120	-1	10
2	+2	128	0	20
3	0	100	0	20
4	0	100	0	20
5	–1	80	+1	30
6	–2	72	0	20
7	0	100	0	20
8	0	100	0	20
9	+1	120	-1	10
10	0	100	-2	6
11	0	100	-	20
12	–1	80	-1	10
13	0	100	+2	34

The effect of roasting temperature (X_1) and time (X_2) on the responses (Y) was fitted by a second-order polynomial model using Eq. (1):

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_{11} X_1^2 + \beta_{22} X_2^2 + \beta_{12} X_1 X_2 \quad (1)$$

where Y predicted the dependent response, β_0 is a constant, β_1 and β_2 are linear coefficients, β_{11} and β_{22} are quadratic coefficients, and β_{12} is the interaction coefficient. X_1 is roasting temperature; X_2 is roasting time. The model adequacy was examined with coefficient of determination (R^2). Statistical significance of the terms in the regression equation was determined for each response using analysis of variance (ANOVA). The significance of each coefficient in the empirical model was excluded or included from the initial model based on the P value ($P \leq 0.05$). Thus, the RSM plots were depicted from the fitted polynomial equations to explain the interactive effects of the two independent variables with the response variable. Superimposition of the RSM plots of selected response variables yielded an optimal range.

3.4 Moisture content and water activity

The roasted chili seasoning (3 g) was weighed into aluminum cans for determination of moisture content in a hot air oven at 105 °C for 6 hr or until a constant weight was obtained (adapted from AOAC, 2000). The water activity of each sample was measured at 25 °C using a water activity instrument (Series 3, AquaLab, Washington, USA). The measurements were taken in triplicate, and mean and standard deviation are reported.

3.5 CIELab color

Each sample was placed in a plastic Petri dish (30 mm in diameter) for measurement of reflectance in the CIE $L^*a^*b^*$ color space using a Color reader (MINOLTA CR-10, Osaka, Japan). Three readings were done at random positions. Measurements were performed in triplicate for each treatment of the samples.

3.6 Sensory evaluation

Sensory acceptability of thirteen seasonings was evaluated by consumers (n = 50) who regularly consumed Thai roasted chili seasoning and were randomly recruited from Rangsit University at Central Location Test (CLT). They were briefly instructed on the testing procedure. Each sample was coded with a three-digit random number, and they were served in three sessions to minimize any residual effect. Each consumer evaluated five, four, and four samples at the first, second, and third session, respectively. The order of sample presentation was fully rotated to minimize bias (ASTM, 1968). Each sample (0.3 g) was packed into a clear plastic cup to facilitate appearance ratings. Consumers were instructed to visually evaluate the acceptability of appearance. Afterward, they were instructed to open the plastic cup, smell the sample, and evaluate the acceptability of odor. Afterward, they were instructed to mixed the sample into 100 mL clear soup (T = 60 °C), taste it, and evaluate their overall liking using a 9-point hedonic scale (1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely). Rating of each sample was completed before proceeding to the next one.

3.7 Statistical analysis and optimization

A predictive model (from Eq. 1) was used to generate contour plots for physicochemical properties and consumer acceptability. The optimal roasting temperature and time were determined by using the superimposed acceptable area (Palomar, Galvez, Resurreccion, & Beuchat, 1994; Garcia, Sriwattana, No, Corredor, & Prinyawiwatkul, 2009) representing all combinations of mixtures that would meet pre-set criteria (maximum or minimum) for an acceptable prototype product. Model verification of the optimum roasting conditions for producing Thai roasted chili seasoning was performed with a new set of data from another experiment. The physicochemical properties and consumer acceptability were analyzed, and these values were statistically compared to the predicted values. All measurements were performed using three independently prepared samples. The results are reported as the mean value ± standard deviation. The data were subjected to analysis of variance (ANOVA) using the SPSS V.12 statistical software package (SPSS (Thailand) Co., Ltd., Bangkok). Duncan's multiple range test at 5% probability was applied to determine significant differences among the means of treatment parameters.

4. Results and discussion

4.1 Preparation of dried ingredients and quality

The moisture content and water activity are important in the preparation of dried ingredients because they are strongly correlated with storage stability (Labuza, Heidelbaugh, Silver, & Karel, 1971). When water activity of dried food is less than 0.65, all microbial growth is inhibited (Park, 2008). Color is an important sensory attribute of the dried products (Inchuen, Narkrugsa, & Pornchaloempong, 2010). The mean values of the physicochemical properties of prepared dried ingredients are shown in Table 2. The average moisture content of dried chilies was 8.15 %wb, water activity was 0.430, and color characteristics were 30.61 for $L*$ (lightness), 31.10 for $a*$ (redness), and 26.93 for $b*$ (yellowness). Wall and Bosland (1993) reported that final moisture content at 8% is ideal because moisture content above 11% could allow aflatoxin and mold to grow. On the other hand, moisture content below 4% causes an excessive color loss (Toontom, Meenune, Posri, & Lertsiri, 2012). This characteristic is regulated by the National Bureau of Agricultural Commodity and Food Standards (2010) (TAS 3001-2010), in which the maximum moisture content of dried chili was set at 13.50%. The average moisture content of fried shallot and fried garlic was 5.39 and 4.74 %wb, respectively, and water activity was 0.46 and 0.44, respectively. The color characteristics for fried shallot were 38.04 for $L*$ (lightness), 6.20 for $a*$ (redness), and 6.76 for $b*$ (yellowness) and for fried garlic were 52.14 for $L*$ (lightness), 6.54 for $a*$ (redness), and 30.26 for $b*$ (yellowness). Therdthai, Wuttijumnong, Jangchud, and Kusucharid (2007) and Utama-ang, Cheewinworasak, Simawonthamgul, and Samakradhamrongthai (2018) revealed that moisture content and water activity should not exceed 5% and 0.60, respectively, to preserve color and that decreasing frying temperature could produce higher lightness. These characteristics are also regulated by Thai Community Product Standards (Thai Industrial Standards Institute, 2020).

Table 2 Physicochemical properties of dried ingredients

Ingredient	Moisture Content (%wb)	a_w	$L*$	$a*$	$b*$
Dried chili	8.15 ± 0.01	0.43 ± 0.01	30.61 ± 0.30	31.10 ± 0.59	26.93 ± 0.58
Fried shallot	5.39 ± 0.13	0.46 ± 0.00	38.04 ± 0.31	6.20 ± 2.73	6.76 ± 4.90
Fried garlic	4.74 ± 0.25	0.44 ± 0.00	52.14 ± 0.53	6.54 ± 1.93	30.26 ± 3.40

Mean ± standard deviation (n = 3)

4.2 Appropriate mixing ratio and roasting conditions of Thai roasted chili seasoning

To determine the optimum ratio between dried ingredients and oil, different ratios (2:1, 1.5:1, 1:1 and 1:2 (w/w)), as shown in Figure 1, were studied, and the results were statistically compared in terms of moisture content, a_w, color and sensory scores. As shown in Table 3, the different ratios had significant differences in physicochemical properties. $L*$ (lightness) increased when increasing the oil content, while $a*$ (redness), $b*$ (yellowness), and a_w decreased. Samples with lower oil content were brighter, much redder, and more yellow. These changes indicated that increasing the proportion of oil in the formula affects the color characteristics. Changes in a_w values and moisture content were similarly observed and affected by increased oil content. Although reduced moisture content and a_w can extend the shelf life of roasted seasoning, they may negatively affect its acceptability to the consumer. The hedonic scores of the five sensory attributes (appearance, color, oil content, odor, and overall liking) of the different ratios between dried ingredients and oil were also investigated. Different mixing ratios affected the appearance and overall liking score ($P \leq 0.05$). Ratios of 2:1 and 1.5:1 (w/w) of dried ingredients to oil received the highest appearance acceptability and overall liking scores ($P \leq 0.05$). This indicated that the products containing high oil content (1:1 and 1:2) were not preferred. We selected the ratio 2:1 to develop in the next step, because the oil content is an important factor in lipid oxidation and rancidity of products. Lipid oxidation will result in significant changes in the sensory properties that can be detected by the consumer and may determine the shelf life of products containing oils (Fennema, 1996). Formulas that use less oil content may prevent rancidity and provide a longer shelf life. Tasaudom, Srapinkaraburi, and Nipronrum (2009) reported that no peroxide values were detected in stored chili paste for 2 months because of the small amount of fat it contained. High peroxide values indicate rancidity (Irwin & Hedges, 2004). This is also regulated by Thai community product standard (2013) (TCPS 321–2013), in which the maximum peroxide values of namphrik phat (roasted chili paste) products was set at 30 meq/kg.

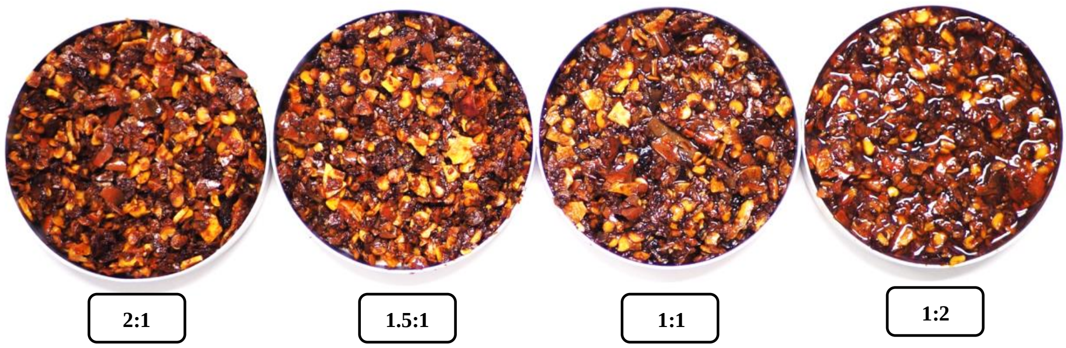

Figure 1 Thai roasted chili seasoning with different ratios of dried ingredients and oil (2:1, 1.5:1, 1:1, and 1:2 (w/w)).

Table 3 Physicochemical properties of Thai fried chili seasoning with different mixing ratios.

Mixing Ratio	$L*$	$a*$	$b*$	a_w	Moisture Content (%wb)
2:1	18.5 ± 1.1c	16.1 ± 1.8a	21.3 ± 1.8a	0.49 ± 0.00a	3.71 ± 0.09a
1.5:1	20.6 ± 1.0b	14.1 ± 0.9b	20.8 ± 1.5a	0.47 ± 0.00b	3.08 ± 0.44b
1:1	21.6 ± 0.8b	12.9 ± 1.0b	15.7 ± 1.7b	0.48 ± 0.01b	3.43 ± 0.18b
1:2	22.9 ± 0.5a	9.0 ± 0.8c	7.2 ± 2.2c	0.46 ± 0.01c	2.68 ± 0.10b

Mean ± standard deviation (n = 3); values within the same column followed by different lower case letters are significantly different ($P \leq 0.05$) by Duncan's multiple range test

Response surface methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes (Raymond & Montgomery, 2002). In the present work, a CCD was applied to determine the effects of roasting temperature

(80-120 °C) and roasting time (10-30 min) in thirteen combinations as shown in Figure 2. The effect of the two independent variables (temperature and time) on the physicochemical properties and sensory acceptability are shown in Table 4. The independent and dependent variables were fitted to the first- and second-order model equation and examined for goodness of fit. The coefficients of determination (R^2) for all properties and sensory qualities were over 0.75, indicating a reasonable fit of the model to the experimental data (Chaiya, Pongsawatmanit, & Prinyawiwatkul, 2015). F-value tests were analyzed to evaluate the goodness of fit of the model. The F-values for all responses were significant at $P \leq 0.05$ (Table 4). The analysis of variance indicated that the predictive models could be represented to predict and optimize the maximum sensory acceptability score of roasted chili seasoning. To aid visualization, three-dimensional response surface plots for the physicochemical properties and sensory attributes from the regression equation (Table 4) were constructed.

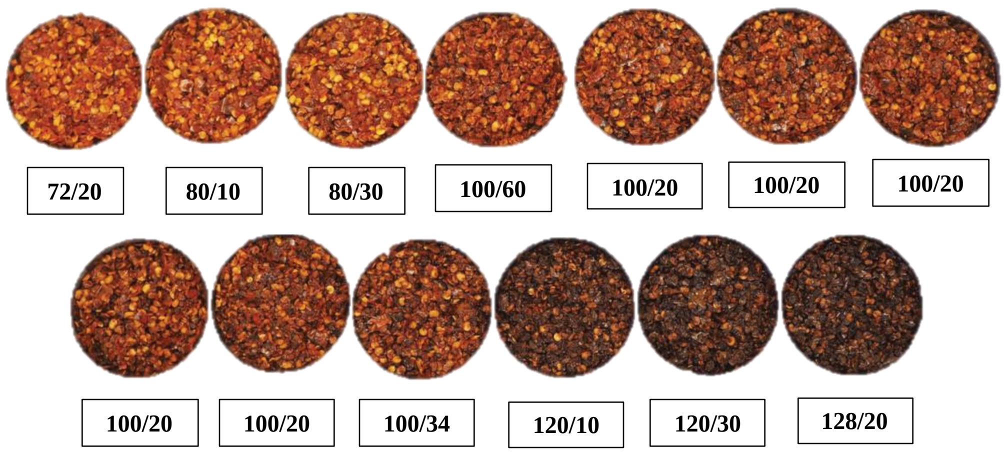

Figure 2 Thai roasted chili seasoning after roasting at different temperatures and for different times.

Table 4 Predicted regression models, R^2 values, and predicted optimal values of physicochemical properties and sensory acceptability of Thai roasted chili seasoning.

Characteristics	Predicted Models†	R^2	Probability
Physicochemical properties			
Moisture (%)	$3.07 + 1.25X_1 - 0.34X_2 - 0.30X_1^2 - 0.22X_2^2 + 0.21X_1X_2$	0.98	0.000††
a_w	$0.39 + 0.013X_1 - 0.0029X_2$	0.77	0.034
L^*	$19.02 + 6.72X_1 - 1.62X_2 + 1.67X_1^2 - 0.41X_2^2 - 0.02X_1X_2$	0.98	0.000
a^*	$44.79 + 7.34X_1 + 1.10X_2 - 13.36X_1^2 - 3.60X_2^2 + 2.42X_1X_2$	0.92	0.001
b^*	$22.35 + 5.56X_1 - 3.19X_2$	0.92	0.000
Sensory acceptability			
Appearance	$6.83 + 1.04X_1 + 0.16X_2 - 0.9X_1^2 - 0.70X_2^2 + 0.11X_1X_2$	0.89	0.003
Color	$6.90 + 1.03X_1 + 0.20X_2 - 1.18X_1^2 - 0.60X_2^2 + 0.072X_1X_2$	0.87	0.005
Odor	$6.37 + 0.45X_1 + 0.32X_2 - 0.44X_1^2 - 0.46X_2^2 + 0.20X_1X_2$	0.89	0.004
Overall liking	$6.85 + 0.82X_1 + 0.17X_2 - 0.86X_1^2 - 0.48X_2^2 - 0.029X_1X_2$	0.97	0.000

† X_1 = roasting temperature (°C) and X_2 = roasting time (min)
†† Significant at $P \leq 0.05$

As indicated in Table 3, a linear model fitted most significantly to a_w and b^* (yellowness) value while a quadratic model fitted to moisture content, L^* (lightness), and a^* (redness) ($P \leq 0.05$). The moisture content, a_w, L^* (lightness), and b^* (yellowness) decreased with an increase in roasting temperature and time (Figure 3), while a^* (redness) showed the highest value when the roasting temperature increased from 85 °C to 100 °C and was negatively affected by temperatures higher than 100 °C (Figure 3). The increased a^* values could be attributed to non-enzymatic browning reactions and destruction of the pigments during heating at high temperature (Chen et al., 2018). Rhim and Hong

(2011) report that degradation of carotenoid pigments and the development of browning compounds caused the pepper powder color to fade from red to brown and black from non-enzymatic browning reactions. A previous report also suggested that roasting temperature and time affect the physicochemical properties and quality of chili powder. a_w and color parameters are reduced with increasing roasting temperature (Pongsawatmanit, Chaethong, & Miyawaki, 2015). Figure 4a-d represents the interaction between roasting temperature and time and their effects on sensory acceptability of Thai roasted chili seasoning. The contour lines took on an elliptical shape, which indicated that the interaction effects of time and temperature were significant. It was evident that the sensory score in terms of appearance, color, odor, and overall liking increased with longer roasting time at low temperature (not more than 100 °C), similar to color value. This clearly indicated that consumers did not like darker colored chili seasoning. High roasting temperature and longer time caused non-enzymatic browning reactions, oxidation, and degradation of pigment and affected flavor compounds and sensory attributes (Chen et al., 2018).

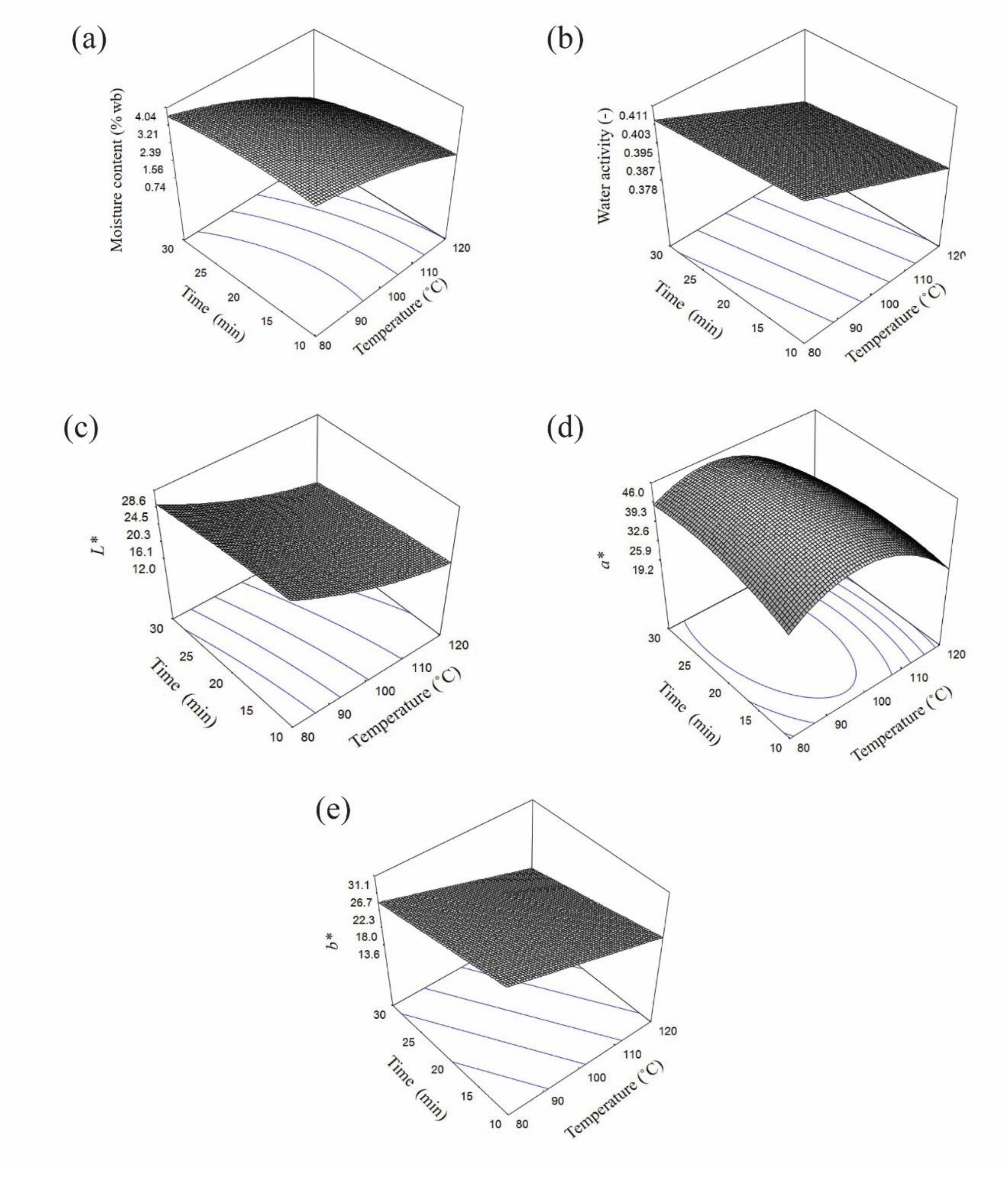

Figure 3 Response surface plot of moisture content, water activity, and color values (L^*, a^*, and b^*) of Thai roasted chili seasoning

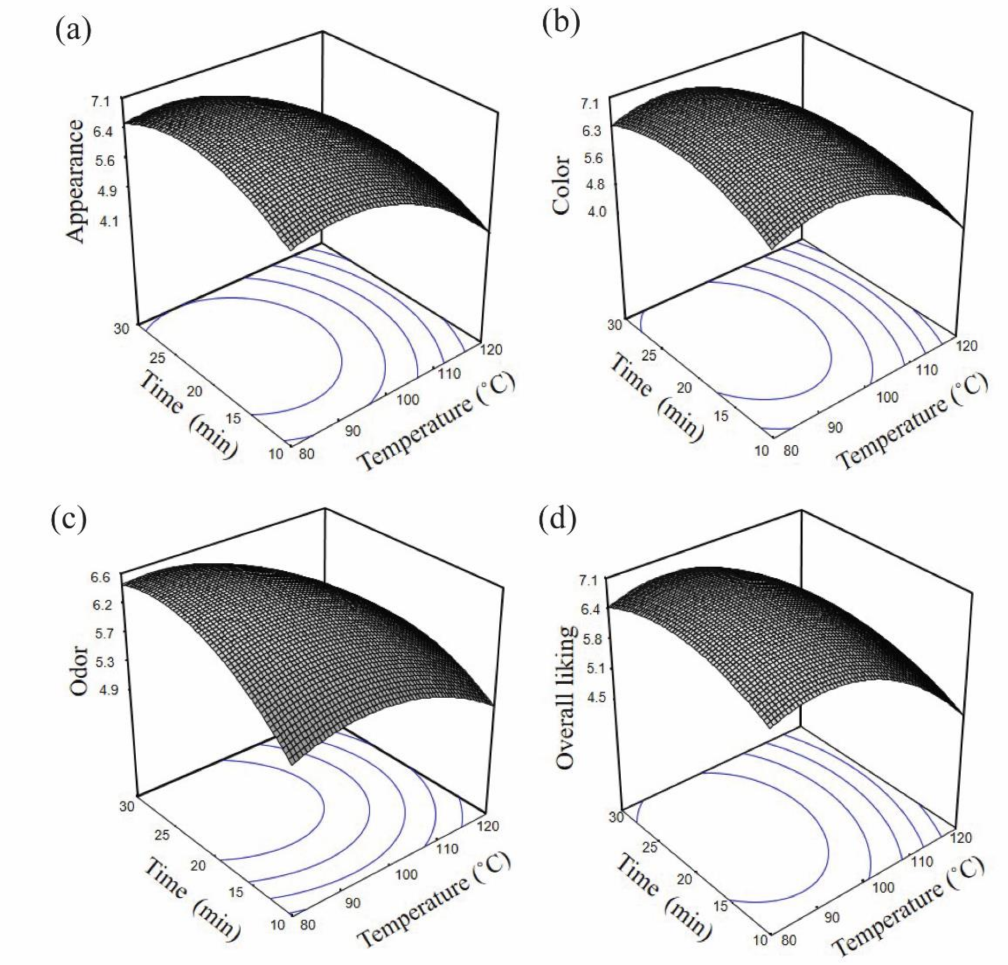

Figure 4 Response surface plot of sensory acceptability of Thai roasted chili seasoning. (a) Appearance, (b) color, (c) odor, and (d) overall liking

Sensory optimization was done using response surface methodology (RSM). Only predicted models of sensory attributes with a coefficient of determination (R^2) value of ≥0.80 were selected to perform the designed contour plots. To determine the optimum roasting conditions, the regions of the contour plot of color characteristics (L^*, a^*, and b^*) and sensory acceptability were superimposed, as shown in Figure 5. The optimal roasting temperature and time corresponding to the criteria each attribute received hedonic ratings ≥6.5. The area of overlap obtained is the shaded region in Figure 5. Any point within this area represents optimal processing conditions that would result in consumer acceptability for all the sensory attributes (hedonic ratings ≥6.5): temperature of 89–93 °C and roasting time of 21-24 min. The point at 91 °C and 23 min was used for model verification, and the experimental results of verification were not significant to the predicted one ($P \leq 0.05$, data not shown). This implied that there was a high degree of fit between the values observed in the experiment and the value predicted from the regression model.

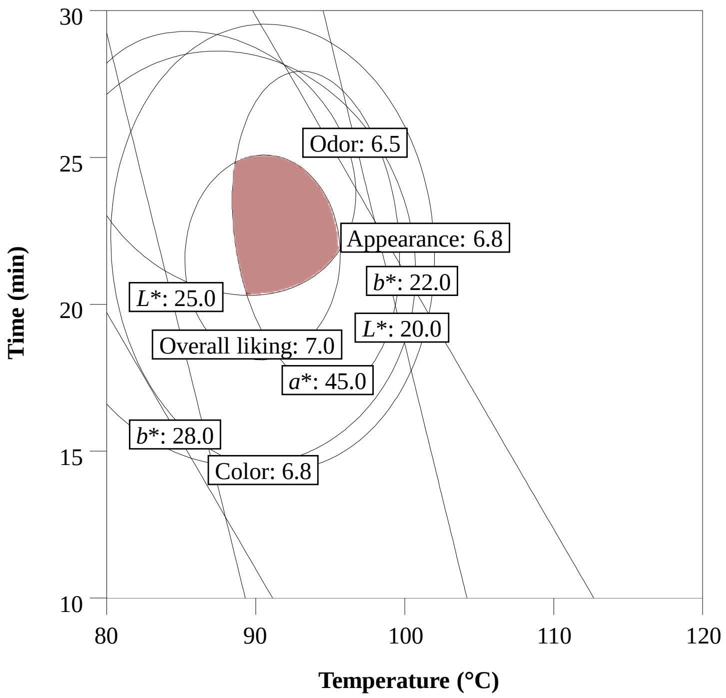

Figure 5 A superimposed contour plot of Thai roasted chili seasoning. The shaded area yields an optimal formulation region (89-93 °C and 21-24 min).

5. Conclusion

The present study examined the process of preparing Thai roasted chili seasoning from dried ingredients. Prepared ingredients (dried chili, fried shallot, and fried garlic) had moisture content <8.20% and $a_w < 0.47$ and can therefore be considered low-moisture foods that meet the standard. The varying mixing ratios of dried ingredients and oil had significant effects on color (*L**, *a**, and *b**) and a_w. Sensory scores indicated that the optimum mixing ratio between dried ingredients and oil was 2:1. RSM was applied to determine the effects of roasting temperature (80–120 °C) and roasting time (10-30 min). The predicted optimum region was 89-93 °C for roasting temperature and 21-24 min for roasting time. Within this optimum region, roasted chili seasoning would have predicted acceptability scores ≥7.0 (moderately liked on a 9-point hedonic scale) for overall liking. Scale-up along with a larger group of consumers should be further studied to improve the process of preparing roasted chili seasoning and provide higher quality.

6. Acknowledgements

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