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Determination of factors effecting on the hardness of soft peanut tofu using screening model

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Abstract

Soft tofu from soy milk appeared for long time ago. However, soft tofu from peanut milk has not been produced much. There has been little research, especially on factors effecting on the hardness of soft tofu. In this research, investigation on main factors (The heated time, $CaSO_4$ content and the pressing force) affecting the structure of tofu products was conducted at the laboratory scale. The hardness of soft peanut tofu was evaluated using the Screening model. This research also shows the dependence of the heated time, $CaSO_4$ content and the pressing force on the hardness of soft tofu. Those factors were not absolutely interacted together. There is the covariant between the heated time, $CaSO_4$ content and the pressing force with the hardness of soft tofu and all of these factors strongly affected the hardness. The optimal hardness was 0.35 N with the heated time was 4.5 min, $CaSO_4$ content was 2.75 % and the pressing force was 40 N.

Key words: $CaSO_4$, Hardness, Lì peanut, Screening model, Soft tofu, Soy milk

Introduction

Tofu, a Chinese traditional food, has been known as the most nutritious and healthiest food. Tofu was widely used by vegetarian diet with a variety of recipes (Veronica, 2008). It made the easy family meals and there are many reasons to do, for instance: cheap, delicious, nutritious, low calories and it can help to control a few health problems (Afamily, 2011). Peanut tofu was quite known to some Asia countries, while it was almost unknown to western countries. We can process tofu from soybean and peanut by many ways. Peanut milk and soft tofu were produced with slight modifications (Thieu, 1996).

Optimization of conditions for processing is one of the most critical stages in the development of an efficient and economic bioprocess. Statistical methodologies involved used mathematical models for designing fermentation processes and analyzing the process results (Bas et al., 2007). Screening model is a simple mathematical model which can find the important factors as the first phase of a project using linear and interaction models.

Therefore, the objective of the present study was to determine the relationship of some factors which affect to the hardness of soft tofu, contributing to the development of the tofu industry in general.

Materials and Methods

Materials

Lì peanut were obtained from Tay Ninh province in Vietnam. Average weight of 1000 seeds is 420g, diameter 7-8mm. Seeds do not have insects and have characteristic odour.

$CaSO_4.2H_2O$ was obtained from Xilong Chemical Company (China).

Treated water (pH=6.7) was obtained from Green Solution Company (Vietnam).

Muslin cloth was obtained from Thanh Cong Company (Vietnam).

Methods

Soft tofu processing

Peanut grains (80 g) were soaked in 200 mL (1:2.5, w/v) of tap water and stored at 28-30 ^oC for 4.5 hours. The soaked peanut was ground with 800 mL water for 5 min at a high speed in Philips Blender (Volume of tank: 2000 mL, 500 W, 15000 r/m, China). After grinding, the slurry was filtered through a muslin cloth and squeezed by hand to obtain peanut milk (You et al., 2012).

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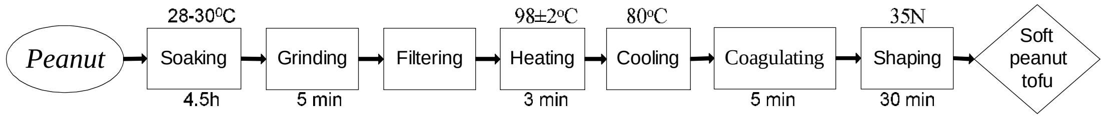

Figure 1. The soft peanut tofu processing.

The peanut milk was heated to boiling point in 98±2°C by the heated machine Midea (1900 W, China), maintained with 3 min (Standard level) while stirring by hand stirrer and cooled to 80°C in the condition room at 30±1°C, relative humidity 60±2%. Soft tofu was prepared by coagulating the peanut milk using the coagulants $CaSO_4$ 2.5% (w/w, standard level). The prepared coagulant was added to the milk and mixture was vigorously stirred for 30 seconds by hand stirrer. The mixture was allowed to stand for 5 min when the curd was separated from the whey and transferred to a wooden mould (6x10 cm) for pressing. The curd was covered by the muslin cloth in the wooden mould. The curd was pressed for 30 min at 35 N (Standard level) letting the water flows out through the bottom hole of the wooden mould. After pressing, tofu was taken out from mould and cut into small samples of 4 x 3 x 2 cm (Quoc et al., 2011). We used INSTRON 5543 mechanical tester (Speed of 5 mm/s, diameter of sensor 3 mm, USA) to measure the hardness of soft tofu.

Figure 2. The soft peanut tofu after taking out the wooden mould.

Experimental design

Screening models were used to determine a few main factors that can affect to the response. In this research, there are three factors including the heated time (x_1), $CaSO_4$ content (x_2) and the pressing force (x_3). It can affect to target the hardness of soft tofu (y). Influence of factors to target function was described according to equation below:

$$y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i<j}^{n} b_{ij} x_i x_j \quad (1)$$

In this study, n-value was 3 so equation (1) can be written:

$$y = b_o + b_1x_1 + b_2x_2 + b_3x_3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 \quad (2)$$

(Canh, 2004).

A common experimental design is one with all input factors set at two levels each. These levels are called `high' and `low' or `+1' and `-1', respectively. A design with all possible high/low combinations of all the input factors is called a full factorial model in two levels (Mary et al., 2003). The design contains a total of 11 experimental trials with a full factorial model fashion and the replications of the central points.

Statistical analysis

The hardness of soft tofu was determined by actual response value. The data reported represent its mean. Statistical significance was evaluated using the Analysis of Variance (ANOVA) and $p<0.05$ was considered as significant (Tuan, 2008). Optimum parameters were defined by the software Modde version 5.0.

Results and Discussion

The hardness of tofu was determined according to Table 2. Based on the full factorial model, result of experimental analysis was presented in Table 3 and 4. According to the ANOVA table, the regression model is significant at the considered confidence level (95%) since the regression has $p_{value}=0.042$ (<0.05).

Table 1. Codes and actual levels of the in dependent variables for design of experiment using model (in this case is screening model/full factorial model).

Independent variables	Symbols	Coded levels		
		-1	0	+1
The heated time (minute)	X_1	1.5	3	4.5
$CaSO_4$ content (%, w/w)	X_2	2.25	2.5	2.75
The pressing force (N)	X_3	30	35	40

Table 2. Two level full factorial composite model and experimental responses of dependent variable y (The hardness of soft tofu, N).

Run No	Coded levels			Real values			The hardness of soft tofu (N)	
	x_1	x_2	x_3	X_1	X_2	X_3	Observed	Predicted(*)
1	-1	-1	-1	1.5	2.25	30	0.22	0.22068
2	+1	-1	-1	4.5	2.25	30	0.27	0.27318
3	-1	+1	-1	1.5	2.75	30	0.23	0.23318
4	+1	+1	-1	4.5	2.75	30	0.28	0.28068
5	-1	-1	+1	1.5	2.25	40	0.23	0.23318
6	+1	-1	+1	4.5	2.25	40	0.27	0.27068
7	-1	+1	+1	1.5	2.75	40	0.3	0.30068
8	+1	+1	+1	4.5	2.75	40	0.33	0.33318
9	0	0	0	3	2.5	35	0.25	0.26818
10	0	0	0	3	2.5	35	0.28	0.26818
11	0	0	0	3	2.5	35	0.29	0.26818

(*): Running the software Modde version 5.0 to predict obtained model

Table 3. Analysis of variance (ANOVA) for the full factorial model.

y	DF	SS	MS	F	p	SD
Total	11	0.8023	0.0729364			
Constant	1	0.791136	0.791136			
Total Corrected	10	0.0111638	0.00111638			0.0334122
Regression	6	0.0101751	0.00169586	6.8614	**0.042**	0.0411808
Residual	4	0.000988635	0.000247159			0.0157213
Lack of Fit	2	0.00012197	6.09848e-005	0.140734	0.877	0.00780928
Pure Error	2	0.000866666	0.000433333			0.0208167

Table 4. Results of regression analysis of the full factorial model.

y	Coeff. SC	Std. Err.	P	Conf. int(±)
Constant	0.268182	0.00474015	5.84382e-007	0.0131608
x_1	0.02125	0.00555831	0.0187284	0.0154324
x_2	0.01875	0.00555831	0.0279575	0.0154324
x_3	0.01625	0.00555831	0.0430904	0.0154324
x_1*x_2	-0.00125003	0.00555831	**0.833084**	0.0154324
x_1*x_3	-0.00375001	0.00555831	**0.536873**	0.0154324
x_2*x_3	0.01375	0.00555831	**0.0686682**	0.0154324
N = 11	Q^2 =	0.748	Cond. no. =	1.1726
DF = 4	R^2 =	0.911	Y-miss =	0
	R^2_{Adj} =	0.779	RSD =	0.0157

The table shows coefficients in the regression equation. The heated time, $CaSO_4$ content and the pressing force are absolutely independent, do not interact together ($p_{value}>0.05$) and have influence to the hardness of tofu (Table 4). Factors have $p_{value}<0.05$, it means these factors effect on the response. Regression equation as below presents dependence of the hardness of soft tofu on three factors quoted above:

$$y = 0.268 + 0.021x_1 + 0.019x_2 + 0.016x_3 \quad (3)$$

Equation (3) showed the regression coefficients of linear term x_1, x_2 and x_3. The pressing force has less impact on the hardness of tofu than $CaSO_4$ content and the heated time. With first-level coefficients: the heated time, $CaSO_4$ content and the pressing force were covariant when comparing with the obtained hardness of soft tofu (The heated time had the strongest influence level).

Table 4 showed the experimental yields fitted the polynomial equation of the first degree well as indicated by high R^2 (Coefficient of determination) value was 0.911. The R^2_{adj} was 0.779 and the Q^2 was 0.748, which indicates that the model is good. For a good statistical model, the R^2 value should be in the range of 0–1.0, and the nearer to 1.0 the value is, the more fit the model is deemed to be; predictive ability of model manifest by Q^2 with fail-safety achieved R^2.

In Figure 2 and 3, the three-dimensional contour plots and response surface plots are displayed according to Equation (3). The graph determined the contribution of the heated time, $CaSO_4$ content and the pressing force on the hardness of soft tofu. The response surface in this research was plane rather than a curved surface. The more heated time, $CaSO_4$ content and the pressing force increase, the harder the hardness was in interval research. Heating the peanut milk denatured the protein, the polypeptide chain was extended, ($-COO^-$) group appeared and linked protein chain together. Protein was concentrated and coagulated. Increasing content of calcium sulphate was tightened protein links until no more carboxyl functional group ($-COO^-$) available. The increase of ion Ca^{2+} maybe influences the taste of tofu. The heat will rise to the hydrophobic links, increase hydrophobic links between the polypeptide, thereby increasing the link between proteins by the ($-COO^-$), made the coagulation protein. As pressing force increases, the hardness increases, this is because the water went out from the curd and created good conditions for arranging structure protein chain. The volume of tofu decreased and protein density was higher than previous curd. The tofu becomes the strongest curd (Quoc et al., 2011).

Using the software Modde 5.0 optimized to predicting the result of optimum condition from regression equation which were the heated time 4.5 min, $CaSO_4$ content 2.75 %, the pressing force 40 N and the hardness of soft peanut tofu 0.3332 N

We conducted a re-test with some received parameter. The hardness of soft tofu achieved 0.35 N with an error of 5 % (Compare with predictive model). Correspondingly, this result has a high reliability.

The parity plot shows a satisfactory correlation between the experimental values and predictive values of the hardness of soft tofu (N) using software Modde 5.0 in 11 experiments shown in Table 2. The result shows this was linear correlation (Figure 4). The matching quality of the data obtained by the model proposed in Equation (3) was evaluated considering the correlation coefficient, R^2, between the experimental and modeled data. The mathematical adjustment of those values generated a R^2. The R^2 value should be in the range of 0–1.0, R^2 was near to 1.0 so the model was apparently better. In this case, R^2 = 0.911 and it was the fit model, revealing that the model only could not explain 8.9% of the overall effects, showing that it is a robust statistical model.

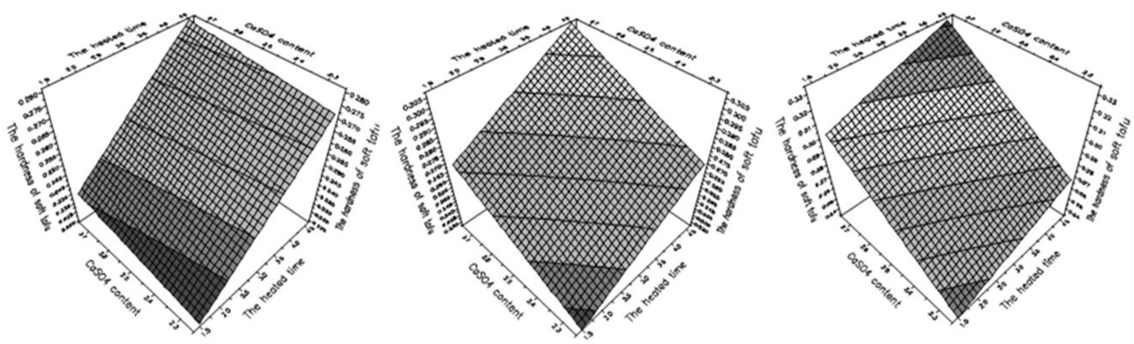

Figure 3. Response surface plot of the hardness of soft tofu when the pressing forces were 30, 35 and 40N.

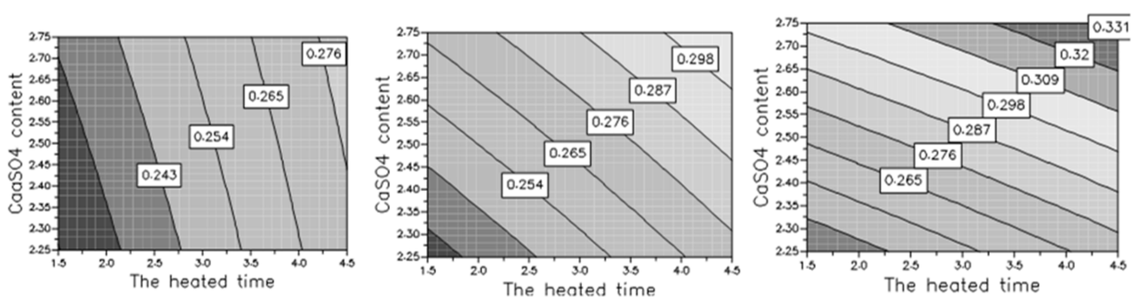

Figure 4. Isoresponse contour plot of the hardness of soft tofu when the pressing forces were 30, 35 and 40N.

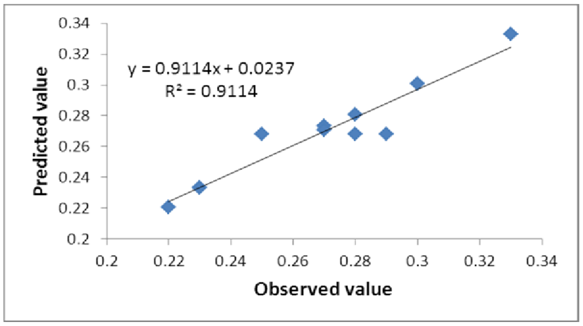

Figure 5. Parity plot showing the distribution of experimental versus predicted values by the mathematical model of the y values.

Conclusions

Conventional optimization studies are time consuming and expensive. To overcome these problems, a screening model was used for the optimization of process conditions. From the present study, it is evident that the use of statistical process condition optimization approach, full factorial model has helped to locate the most significant conditions with minimum effort and time. From studies quoted above, we come to a conclusion that the heated time, CaCO4 content and the pressing force were the main factors that have strong influence on the hardness of soft peanut tofu.

Using the optimal method of target function, we exposed regression equation and this equation can be applied on actual model:

$y = 0.268 + 0.021x_1 + 0.019x_2 + 0.016x_3$

Based on the regression equation, three factors including the heated time, CaSO4 content and the pressing force were determined affect the hardness of soft tofu. These factors were absolutely independence, not interactive together, level of effects did not change much and it had the covariant with hardness. This model had the high R2, R2adj and Q2 and was absolutely according to actual production. It was quite easy to select and modify some parameters in tofu processing.

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