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Optimization of Vacuum Frying Condition for Shallot

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ABSTRACT

Nowadays, healthy food has become more popular. This research was aimed to develop fried snack from shallot which is also good for human health. Normally fried snack is tasteful, but not healthy. This was due to high fat content. To reduce fat content from frying process, vacuum frying was used in this research. Using the central composite design, experiments were conducted at 550 -700 mm Hg of vacuum, 85-120°C and 5-25 minutes. From the obtained experimental data, empirical models were established to express the relationship between process parameters (including vacuum level, frying temperature and time) and product quality. Based on the models developed, the frying conditions were optimized using least square criterion. To minimize fat content of fried snack, shallot should be fried under vacuum 551 mm Hg and 108°C for 13 minutes. The optimal vacuum frying condition was conducted to compare with the deep fat frying. The result showed the improvement of product color as well as a decrease in fat content in the finished product. After 7 continuous vacuum frying processes, a slight change in acid value for the oil was found. Therefore, the optimal vacuum frying condition could be applied to produce fried snack from shallot.

Key words: vacuum frying, snack, model, optimization, shallot

INTRODUCTION

From previous researches, shallot was proven to increase high density lipoprotein (HDL) cholesterol, reduce low density lipoprotein (LDL), reduce cholesterol in the blood and control blood sugar (http://dpc12.ddc.moph.go.th/new/f.htm.). Thus it would be beneficial to develop a snack from shallot.

Deep fat fried snack is one of the most tasteful products. However, high fat content could reduce consumption due to a health concern issue. Fat content absorbed into food layer is dependent on process time, surface area and nature of raw materials. Not only is there high fat content, but deep fat frying also uses high temperature and is an opened system. This speeds up oxidation and thereby rancidity development. Vacuum frying could be used to reduce fat content, frying temperature and slow down rancidity of oil. Garayo and Moreira (2002) found that vacuum frying could reduce the fat content of French fries to 26.63% (which is normally 35.3- 44.5 % by deep fat frying). Shyu and Hwang (2001) found the process condition for sliced apple should be at 740 mm Hg of vacuum, 90-110°C and 5-30 minutes.

To optimize the frying condition, the effects of the process parameters on the product quality have to be clearly understood. A model can

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be one of the methods for expressing this relationship between process parameters and quality factors. With experimental data, empirical models can be developed. Although empirical models purely rely on data, it is suited for the simulation of food processes. This is because the complexity of food processes that normally involve extensive chemical mechanisms. Moreover, the structure of raw materials is not consistent (Kahyaogly and Kaya, 2005).There have been some previous researches (Palomar *et al*., 1994; Thakur and Saxena, 2000) that applied empirical models for further optimization of food products. Therefore, this study was aimed to develop empirical models to describe the effect of vacuum level, frying temperature and frying time on color, texture, moisture content and fat content in fried shallot. Optimization would be done to design the optimal vacuum frying process for shallot.

MATERIAL AND METHOD

Material

Before placing in a frying chamber, fresh shallot was washed, peeled and chopped into small pieces.

Methods

Frying

Using 5,000 ml of palm oil, 200 g shallot was fried in a vacuum fryer (OFM Company) under various conditions. The experimental frying conditions were conducted using Central Composite Design (CCD). There were 3 process parameters including vacuum (500-700 mm Hg), frying temperature (85-120°C) and frying time (5-25 minutes). When the frying process was finished, the product was sent to spin at 1000 rpm for 3 minutes to reduce the fat content. After spinning, the obtained products were brought to determine the quality as follows:

- Color (L*, a, b) by spectrophotometer (Minolta CM – 3500 d)
- Hardness by texture analyzer (Lloyd TA 500)
- Moisture content (AOAC, 2000)
- Fat content (AOAC, 2000)

Modeling and Optimization

The experimental data was used to fit empirical models. Independent variables consisted of vacuum, frying temperature and frying time while dependent variables consisted of %yield, L*-value, hardness, moisture content and fat content. Model coefficients were analyzed using Matlab version 6. To evaluate model performance, the correlation coefficient (r) and the mean square error (MSE) between experimental data and predicted data were calculated. Based on the models developed, the frying process was optimized using least square criterion technique. The objective was to minimize fat content in the finished product with constrains of product quality range. After 3-minute spinning, the quality of the finished product fried under the optimum processing condition was compared with the deep fat fried product with its oil already drained out. In addition, the change in acid value (AOCS, 1997) during frying was determined.

RESULTS AND DISCUSSION

Frying

The quality of the fried shallot is presented in Table 1. According to Table 1, increasing the vacuum level could shorten the frying time. Longer frying time reduced the moisture content; however, product lightness (L*-value) was decreased and fat content was increased. Decreasing frying temperature could produce higher lightness; however, within the range of experiments, temperature could not be less than 100°C. Otherwise the product would be undercooked.

Table 1 Quality of fried shallot.

Experiment	Vacuum (mm Hg)	Temperature (°C)	Time (minutes)	Yield (%)	Quality					
					Physical quality				Chemical quality	
					Hardness (N)	Color			Moisture content (%)	Fat content (%)
						L*	a*	b*		
1	550	90	10	29.08	0.13	48.61	4.63	16.64	25.16	25.53
2	550	90	20	23.17	3.03	56.19	4.22	18.25	7.57	30.52
3	550	110	10	24.64	3.70	56.49	6.74	23.80	3.95	33.55
4	550	110	20	23.58	2.17	43.25	13.40	24.51	3.33	34.76
5	650	90	10	25.30	0.20	55.23	3.42	16.59	19.89	26.27
6	650	90	20	24.75	0.17	53.55	3.61	15.33	20.07	31.27
7	650	110	10	23.47	2.07	58.29	8.16	27.75	3.93	38.82
8	650	110	20	22.90	4.23	48.77	12.43	28.59	3.16	43.28
9	700	120	25	23.43	2.17	35.55	10.37	13.97	1.43	45.38
10	700	100	15	26.38	2.59	46.08	6.15	21.78	3.53	40.44
11	600	100	25	23.83	3.50	46.80	11.06	26.01	3.92	32.71
12	600	120	15	24.08	3.80	43.79	13.35	25.61	2.10	38.73
13	500	85	5	38.27	0.20	55.17	5.42	8.85	58.60	21.64
14	500	100	15	23.55	4.43	51.41	7.24	21.95	4.98	33.81
15	600	100	5	26.18	0.40	49.93	5.63	10.10	18.06	30.00
16	600	85	15	26.18	0.30	47.18	6.02	9.64	17.48	29.68
17	600	100	15	23.82	3.03	54.55	7.80	23.94	4.60	35.54
18	600	100	15	23.36	4.03	60.63	5.13	24.19	4.82	36.37
19	600	100	15	21.55	3.23	53.89	6.26	21.91	4.26	35.67
20	600	100	15	23.78	3.23	49.97	8.03	22.33	4.71	34.86

Modeling and Optimization

Based on experimental data from Table 1, empirical models were developed as follows:

$$yi = b_0+b_1x_1+b_2x_2+b_3x_3+b_4x_1x_2+b_5x_1x_3+b_6x_2x_3+b_7x_1^2+b_8x_2^2+b_9x_2^3+b_{10}x_1^3+b_{11}x_2^3+b_{12}x_3^3+b_{13}x_1^4+b_{14}x_2^4+b_{15}x_3^4 \quad (1)$$

where y_i (i=1…5) = %yield (y_1), L*-value (y_2), hardness (y_3), moisture content (y_4) and fat content (y_5)

x_1 = Frying temperature (°C)

x_2 = Vacuum level (mmHg)

x_3 = Frying time (minute)

b_i (i=0…15) = Model coefficients (Table 2)

By comparing between experimental data and predicted data, model performance was shown in Table 3. MSEs were comparable to the range of each experimental data set. In addition, correlation coefficients were reasonably high. Therefore, overall model performance was reasonably good.

Based on the models developed, frying process was optimized with objective and constraints which were from the acceptable range of product quality and limitation of process operating condition, as follows:

Objective (to minimize fat content)

Minimize y_5 (2)

Subject to:

L*-value	$50 < y_2 < 60$	(3)
Texture value (N)	$3 < y_3 < 7$	(4)
Moisture content (%)	$2 < y_4 < 5$	(5)
Frying temperature(°C)	$85 < x_1 < 120$	(7)
Vacuum level (mmHg)	$500 < x_2 < 700$	(8)
Frying time (minute)	$5 < x_3 < 25$	(9)

Solving the problems using least square criterion, the optimum frying condition was found at vacuum 551 mm Hg, 108°C and 13 minutes. Comparing to deep fat frying, the optimum vacuum frying could reduce the fat content by approximately 17% (Table 4). In addition, the color (L*-value) of the vacuum fried product was lighter than the one from the deep fat frying process. Therefore, vacuum frying at the optimum condition could improve product quality. Furthermore, a continuous frying process was conducted to investigate the change of oil quality during frying. After 7 times of continuous frying,

Table 2 Model coefficients.

Model coefficients	Yield (y_1)	L*-value (y_2)	Hardness (y_3)	Moisture content (y_4)	Fat content (y_5)
b_0	-	1187.20	-141.06	518.39	1394.30
b_1	1.2996	-6.7275	0.1063	-0.8366	-5.4445
b_2	-	3.0382	2.1274	-2.8715	-9.6315
b_3	-6.3982	8.0949	0.6398	-10.0378	0.4664
b_4	-0.0005	0.0027	0.0019	-0.0038	0.0036
b_5	0.0026	0.0011	0.0010	0.0087	0.0018
b_6	0.0063	-0.0527	-0.0029	0.0207	-0.0058
b_7	-0.0027	0.0111	-0.0003	0.0009	0.0089
b_8	-0.0844	-0.0225	-0.0146	0.0200	0.0867
b_9	0.4049	-0.2365	-0.0211	0.0603	0.0067
b_{10}	0.0000	0.0000	-	-	0.0000
b_{11}	0.0011	0.0000	-	-	-0.0003
b_{12}	-0.0174	0.0045	-	-	-0.0011
b_{13}	0.0000	-	-	-	-
b_{14}	0.0000	-	-	-	-
b_{15}	0.0003	-	-	-	-

Table 3 Model performance of empirical models.

Performance	% Yield (y_1)	L*-value (y_2)	Hardness (y_3)	Moisture content (y_4)	Fat content (y_5)
r	0.9334	0.8615	0.9235	0.9412	0.9771
MSE	1.5046	8.9186	2.5485	2.0048	1.4034

Table 4 Comparison of fried product characteristics from different frying processes.

Frying process	Moisture content (%)	Fat content (%)	Color (L*)	Texture (N)
Vacuum frying (optimum condition)	3.93	37.33	55.58	3.10
Deep fat frying	5.30	54.54	35.09	N/A

the acid value was gradually increased from 0.19 mg KOH/ g sample to 0.29 mg KOH/ g sample, as shown in Figure 1. The acid value was still in the low range. Some products such as milk powder and extra-virgin oil normally contain acid values of 1.2 mg KOH/ g sample and 0.6 mg KOH/ g sample, respectively. This was possibly due to the vacuum condition which slowed down lipid oxidation.

CONCLUSION

Empirical models were developed to describe the relationship between frying process

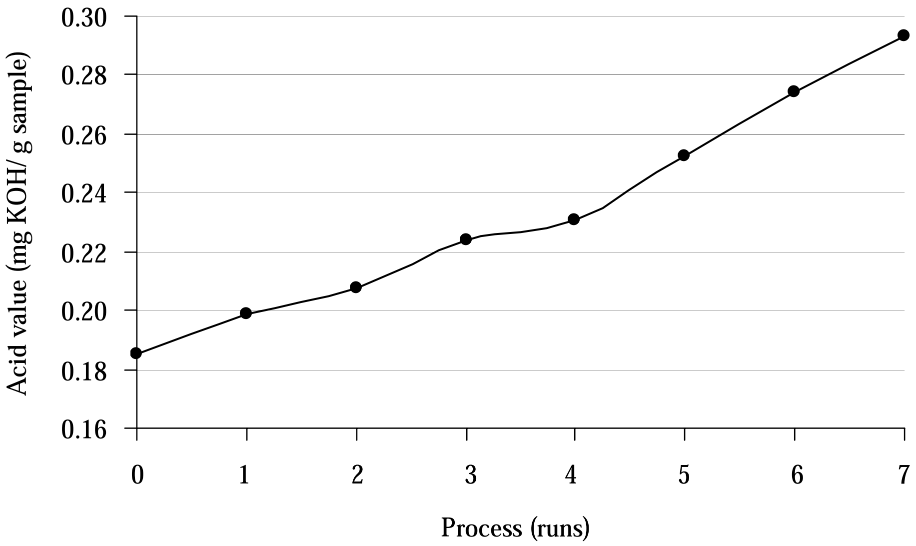

Figure 1 Change of acid value in oil during the continuous vacuum frying condition.

parameters and product quality. The model performance was reasonably good. Thus, the models were used for optimization. Based on the models, the optimal frying condition for red onion was at vacuum 551 mm Hg, 108 °C and 13 minutes. The optimal vacuum fried condition was proven to reduce fat content in fried shallot by comparing it with the deep fat frying process. The fried product color could also be improved. In addition, vacuum frying could slow down the change of acid value of oil during the continuous frying process.

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