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# Development of Optimum Processing Conditions in Air Dried Garlics Using Response Surface Methodology

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## Abstract

The effects of salt concentration, immersion time in a salt solution prior to air dehydration and heating of air temperature during dehydration upon the browning reaction and pyruvic acid content of air dried garlics to a 6.5% moisture content(wet basis) were analyzed by a response surface methodology(RSM). Those values were also predicted by using a second degree polynomial regression model. Heating of air temperature was the most significant factor affecting the both browning reaction and pyruvic acid content. Salt concentration had more influence to browning reaction than immersion time, whereas immersion time was more important factor than salt concentration on a retention of pyruvic acid, suggested different processing conditions. While the processing conditions to minimize the browning reaction(O.D.=0.009) were 0.3% of salt solution, 9 min of immersion time and 50℃ of air temperature compared to control(O.D.=0.022) of air dehydration at 50℃. Pyruvic acid contents were maximized(174 μmole/g garlic solid) at the 0.1% of salt solution, 3 min of immersion time and 50℃ of air temperature compared to control(147μmole/g garlic solid) of air dehydration at 50℃.

## Introduction

Dehydrated garlics and powders are widely used in many processed foods or seasoning blends. Garlics undergo extensively physico-chemical changes during conventional dehydration processes[1]. Therefore, many researchers investigated solvent treatments as pretreatments before dehydration and optimum process conditions to minimize physico-chemical changes during dehydration. The characteristics of dehydrated product such as texture, color, flavor, dehydration ratio and retention of nutrients are likely to be affected by the solvent used[2,3]. Both sulfuring and sulfiting of garlic prior to air dehydration improved the color of the product, but significantly reduced its flavor and completely destroyed antibacterial activity[4-6]. Three minutes of immersion time treatments with a 0.3% phosphate solution before air dehydration reduced browning color development and repressed pyruvic acid reduction of garlic during dehydration. Also, the air temperature during dehydration of garlic should preferably be lower than 60℃ with a 0.5g/cm² tray load.

The objectives of this study were to determine the optimum processing conditions and to develop predictive models based on minimizing browning reaction and maximizing pyruvic acid content during air dehydration, which attribute quality index to dehydrated garlics[1].

## Materials and Methods

### Materials

Garlics(*Allium sativum* L.) used in this study were obtained from the 1989 harvest. The moisture content of garlics was 67.3% on a wet basis. The garlics were manually peeled and sliced to 3mm thickness using a food processor(Sunbeam, oskar).

### Experimental design

In this study, three levels and three factors($3^3$ factorial design) were adopted[11]. RSM designs were undertaken with salt concentration(%), immersion time(min) and air temperature(℃). Each of 27 observations were made on browning reaction and pyruvic acid content, respectively.

The regression coeffecients(Ai) represented an interaction effects of the independent variables were estimated with a second degree polynomial regression model using statistical analysis system (SAS)[10].

$$Y = A_0 + A_1X_1 + A_2X_2 + A_3X_3 + A_4X_1^2 + A_5X_1X_2 + A_6X_2^2 + A_7X_1X_3 + A_8X_2X_3 + A_9X_3^2 \qquad (1)$$

, where independent variables, X1, X2 and X3 were salt concentration(%), immersion time(min) and air temperature(℃), respectively for browning reaction(O.D. units) and pyruvic acid content (μmole/g garlic solid).

### Salt treatments

Approximately 100g garlic slices(wet weight basis) were added to a 400mℓ salt solution containing different salt concentrations(0.1, 0.2 and 0.3%) at constant 15℃ temperature. Also, varying lengths of immersion times(3, 6 and 9 min) were added to the constant factors according to a statistical response surface design.

### Air dehydration

Garlics were dried in a cabinet drier at 50, 60 and 70℃ with a 3m/sec air velocity directly after salt was treated to a 6.5% moisture content (wet basis) on a 0.5g/cm² tray load.

### Determination of moisture content

Moisture content was determined after drying garlics using a vacuum even(Yamato vacuum drying oven, DP-41) at 70℃ and 27 in Hg. for 24 hr.

### Determination of browning reaction

Browning reaction was determined[12] by putting a 1g dehydrated garlic powder in a 250mℓ flask containing 40mℓ of distilled water and 10mℓ of 10% trichloroacetic acid solution. The flask covered with parafilm was allowed to remain at room temperature for 2 hr with occasional shaking. After the solution was filtered through Tyro No. 2 filter paper, the O.D. of the eluent was read at 420nm using a spectrophotometer(Shimadzu double beam spectrophotometer, UV-200S).

### Determination of pyruvic acid content

Total pyruvic acid content was determined according to the method of Schwimmer and Weston[13].

## Results and Discussion

### Effect of salt concentration, immersion time and air temperature on browning reaction

Figure 1 shows the effects of salt concentrations (0.1-0.3%), immersion times(3-9min) and air temperatures(50-70℃) on browning reaction. As the salt concentration and immersion time were increased, the browning reaction was decreased at all air temperature ranges(50-70℃). This fact indicated that the more salt molecules were diffused from the solution into garlics with increasing the salt concentration and immersion time, which reduced the phenolase activity[14]. One limitation of using above 0.3% of salt concentration was due to the salty flavor. Also, the degree of browning reaction during air dehydration was increased rapidly with increasing air temperature between 60 and 70℃ rather than between 50 and 60℃. The effect of temperature on the rate of browning during air dehydration was described as the $Q_{10}$ values, which increased in temperature range from 3 to 6.5 fold[12], without any pretreatment before air dehydration. The most significant factor was air temperature for browning reaction as shown in Table 1. The second and third factors were salt concentration and immersion time, respectively. According to this study, minimum browning reaction during air dehydration could be carried out using pretreatments such as salt treatments in 0.3 % of salt solution with 9 min of immersion time and 50℃ of air temperature(O. D.=0.009) compared to control(O.D.=0.022) dried at 50℃ of air temperature.

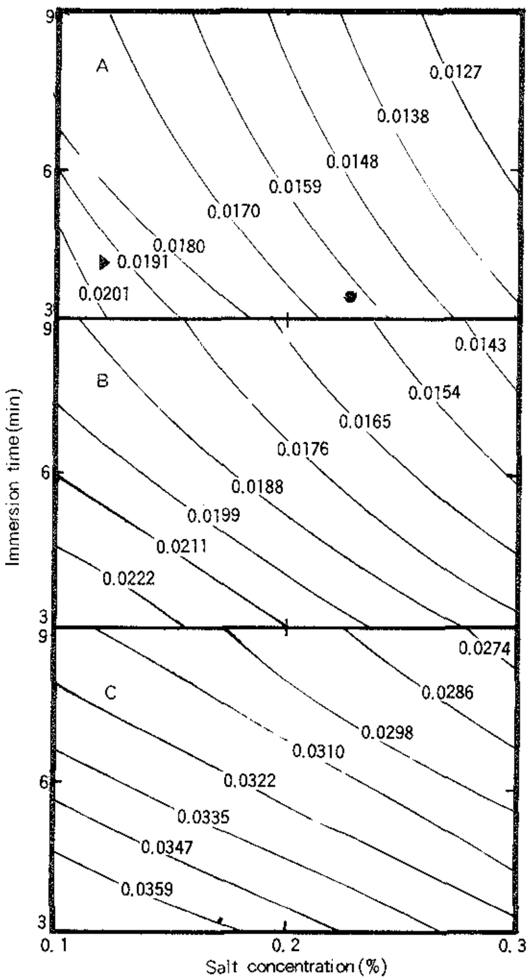


Fig. 1. Browning reaction as a function of salt concentration, immersion time and air temperature.
A, B and C represent 50, 60 and 70℃ of air dehydration, respectively. O. D. units at 420nm for browning reaction of control dried to 6.5% moisture content(wet basis) at 50, 60 and 70℃ of air dehydration were 0.022, 0.032 and 0.047, respecitively.
▶O. D. at 420nm

Effect of salt concentration, immersion time, and air temperature on pyruvic acid content

Pyruvic acid values in dehydrated garlics would be of considerable practical importance in that total pyruvic acid may be of value in assessing at least certain aspects of the flavor quality of dehydrated garlics[1]. A 0.1% of salt concentration had most effective concentration for pyruvic acid content at all air temperature ranges(50, 60 and 70℃) as shown in Fig. 2. Optimum immersion time for pyruvic acid content was 3−4 min at 50℃ of air dehydration. At the 60 and 70℃ of air dehydration temperatures, optimum immersion time was for 4−5 min. A 50℃ of air dehydration produced higher pyruvic acid content compared to 60 and 70℃ of air dehydration. The reduction of pyruvic acid content during processing was due to destruction of structure during slicing, inactivation of allinase and loss of substrate during air dehydration[7]. A maximum retention of pyruvic acid(174μmole/g garlic solid) during air dehydration could be achieved by 3 min of immersion time in 0.1% of salt concentration with 50℃ of air temperature compared to control (147μmole/g garlic solid) dried at 50℃ of air temperature. Likewise in browning reaction, the most significant factor was air temperature for pyruvic acid content. However, the second and third factors were immersion time and salt concentration, respectively as shown in Table 1.

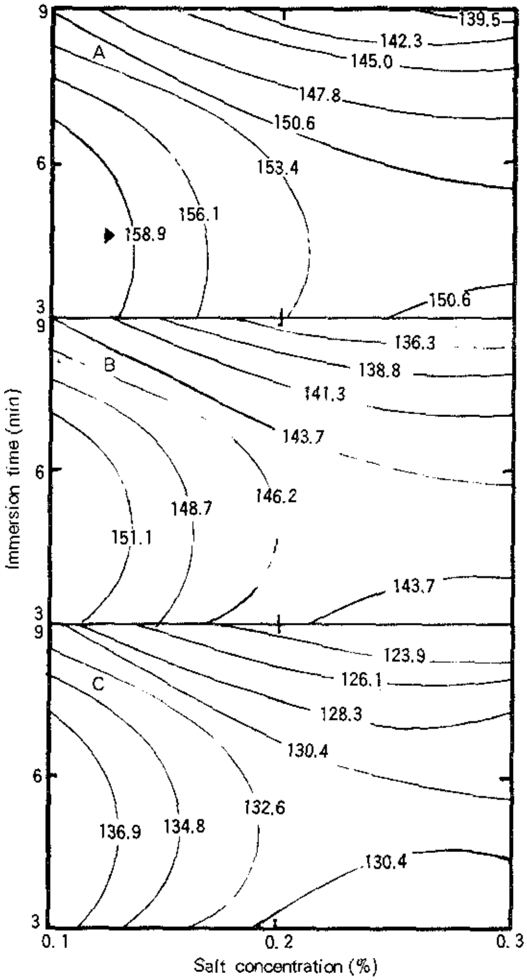


Fig. 2. Pyruvic acid content as a function of salt concentration, immersion time and air temperature.
A, B and C represent 50, 60 and 70℃ of air dehydration, respectively. Pyruvic acid contents of control dried to 6.5% moisture content(wet basis) at 50, 60 and 70℃ of air dehydration were 147, 138 and 121 μmole/g garlic solid, respectively.
▶ μ mole/g garlic solid

Table 2. Regression coefficients of the second degree polynomials for two response variables

| Coefficient[a)] | Browning reaction[b)] | Pyruvic acid content[b)] |
|---|---|---|
| $A_0$ | 0.036296 | 170.962960 |
| $A_1$ | −0.003778 | −19.333333 |
| $A_2$ | −0.003556 | 15.111111 |
| $A_3$ | −0.012278 | −0.944444 |
| $A_4$ | −0.000056 | 3.111111 |
| $A_5$ | 0.000167 | 0.250000 |
| $A_6$ | 0.000611 | −5.722222 |
| $A_7$ | 0.000417 | 0.583333 |
| $A_8$ | −0.000750 | 1.166667 |
| $A_9$ | 0.005278 | −3.222222 |
| $R_2$ | 0.975800 | 0.739800 |

a) There are coefficients of eq. 1 and each independent variables, $X_1$, $X_2$ and $X_3$ is transformed to 1, 2 and 3 as increasing the level.
b) Each independent variables, $X_1$, $X_2$ and $X_3$, represents salt concentration, immersion time and air temperature, respectively.

### Fitting the models

Equation 1 was fitted to the experimental data. Two models(Table 2) were obtained and tested to fittness by coefficient of determination($R^2$). Based on the coefficient of determination, browning reaction($R^2$=0.9758) was highly fitted to the experimental data compared to pyruvic acid content ($R^2$=0.7398).

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Table 1. Analysis of variance for the effect of the three process variables on the two responses

| Process variables | Browning reaction | | Pyruvic acid content | |
|---|---|---|---|---|
| | F-ratio | Proability | F-ratio | Proability |
| Salt concentration | 15.60 | 0.0001 | 3.54 | 0.0283 |
| Immersion time | 10.91 | 0.0001 | 4.17 | 0.0155 |
| Air temperature | 146.18 | 0.0001 | 12.80 | 0.0001 |

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# 반응 표면 분석법을 이용한 마늘 열풍건조 공정의 최적화

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## 요 약

열풍건조전 소금처리로써 소금농도와 침지시간 및 건조중 열풍온도에 따른 열풍건조한 마늘(습량기준으로 6.5% 수분도)의 갈색화 반응과 pyruvic acid 함량에 미치는 영향을 반응 표면 분석법으로 조사하였다. 또한, 나타난 수치들을 이차 다항 회귀 모델로써 예측하였다. 갈색화 반응과 pyruvic acid 함량에 가장 큰 영향을 미치는 요소는 열풍온도이었다. 갈색화 반응에서는 그 다음 소금농도와 침지시간 순으로 영향을 미친 반면에 pyruvic acid함량에서는 침지시간과 소금농도순이었다. 50℃로 열풍건조시킨 대조구(O.D.=0.022)와 비교하여 열풍건조중 갈색화 반응을 최소화 시키는 공정(O.D.=0.009)으로는 0.3%의 소금농도와 9분간의 침지 및 50℃의 열풍온도이었다. 또한, pyruvic acid 함량은 50℃로 열풍건조시킨 대조구(147μmole/9 garlic solid)와 비교하여 0.1%의 소금농도와 3분간의 침지 및 50℃의 열풍온도 공정에서 최대치(147μmole/9 garlic solid)를 나타내었다.