



Optimization of the roasting temperature and time for preparation of coffee-like maize beverage using the response surface methodology

Kwang-Sup Youn^a, Hun-Sik Chung^{b,*}

^a Department of Food Science and Technology, Catholic University of Daegu, 330 Geumrak 1-ri, Hayang-eup, Gyeongsan 712-702, Republic of Korea

^b Food and Bio-Industry Research Institute, Kyungpook National University, 1370 Sankyuk-dong, Buk-gu, Daegu 702-701, Republic of Korea

ARTICLE INFO

Article history:

Received 15 April 2011

Received in revised form

18 August 2011

Accepted 26 September 2011

Keywords:

Maize

Roasting

Hot water extraction

Beverage

Response surface methodology

ABSTRACT

The response surface methodology (RSM) was used to determine the optimal roasting temperature and time for preparing a coffee-like beverage from maize kernels. Maize kernels were roasted at different temperatures (160–240 °C) for different lengths of time (10–50 min) and subsequently extracted with hot water. Yield, levels of free sugar and phenolic compounds, antioxidant activity, and sensory scores for overall preference of the maize beverage were significantly affected by the roasting conditions. Roasting temperature was the most important factor affecting the quality indicators of the maize beverage. Surface and contour plots indicated that the optimal roasting temperature and time were 207 °C and 24 min, respectively.

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1. Introduction

Maize (*Zea mays* L.) kernels are steamed, boiled, grilled, puffed, or milled in food processing and cooking and either consumed directly or used in to generate processed products like cornmeal, starch, oil, sugar, and ethanol. In Korea, maize kernels are traditionally roasted and extracted with hot water. The extracts are drunk as a coffee-like beverage. Roasting is the key procedure in the preparation of the maize beverage, because the characteristic flavor of the beverage is produced during the roasting process. However, the control parameters of the roasting process are undefined and dependent on the experience of the operators.

In the food industry, roasting is used to improve and alter food quality, to extend the shelf-life of foods, and to improve the processing efficiency of subsequent treatment. These beneficial effects of roasting are decisively affected by the roasting conditions. The most important conditions of the roasting process are the temperature and time. Optimal required roasting temperatures and times are dependent on several factors, such as the degree of roast required, the roaster type, and the type, variety, maturity, and moisture content of the raw material (Mendes, de Menezes, Aparecida, & da Silva, 2001). The effects of roasting conditions on chemical components in *Cassia occidentalis* seeds (Medoua &

Mbofung, 2007), cocoa beans (Redgwell, Trovato, & Curti, 2003), coconuts (Jayalekshmy & Mathew, 1990), coffee beans (Deshpande & Aguilar, 1975; Oliveira, Franca, Gloria, & Borges, 2005), hazelnuts (Ozdemir et al., 2001), *Perilla frutescens* seeds (Longvah & Deosthale, 1998), pistachio nuts (Yazdanpanah, Mohammadi, Abouhossain, & Cheraghali, 2005), soybean (Kato et al., 1981; Lee & Lee, 2009), wheat, barley, and green gram (Gahlawat & Sehgal, 1993) were analyzed. In addition, the effects on the colour of hazelnuts (Ozdemir & Devres, 2000), cocoa beans (Krysiak, 2006) and peanuts (Moss & Otten, 1989); on the textures of coffee beans (Pittia, Rosa, & Lerici, 2001), hazelnuts (Saklar, Ungan, & Katnas, 1999) and sesame seeds (Kahyaoglu & Kaya, 2006); on the storability of peanuts (Cammerer & Kroh, 2009); and on extraction efficiency of cocoa butter (Asep et al., 2008) and sesame seed oils (Kikugawa, Arai, & Kurechi, 1983) have been reported. To improve the roasting effects, the roasting conditions can be optimized using a statistical technique like response surface methodology (RSM), which is based on changes in the physicochemical quality indicators during roasting.

RSM is a useful tool to describe quality indicators during food processing (Thompson, 1982). It has been applied successfully to various methods of food processing. Its main advantage is its ability to decrease the number of experimental runs required to provide sufficient information to obtain statistically sound results. With regard to roasting processes, the roasting conditions for coffee beans (Mendes et al., 2001), pistachio nuts (Kahyaoglu, 2008), and

* Corresponding author. Tel./fax: +82 53 950 6781.

E-mail address: goodchung@korea.com (H.-S. Chung).

hazelnuts (Uysal, Sumnu, & Sahin, 2009) were optimized by RSM procedures. This suggests that the same is possible with the roasting conditions for maize, with the aim to improve the quality of the maize beverage. However, no information is available regarding the roasting conditions for maize kernels. Establishing the roasting conditions for maize on the basis of a limited number of variables may lead to inadequate quality of the roasted product. Therefore, to ensure the best possible product, the roasting conditions for maize kernels should be optimized by considering many variables.

The present study aimed to investigate the effects of roasting temperature and time on the nutritional and organoleptic quality properties (extraction yield, browning index, free sugar content, phenolic compounds, antioxidant activity, and overall preference) of the beverage prepared from the roasted maize kernels and to establish the optimal roasting conditions for the production of maize beverages that have high quality properties.

2. Materials and methods

2.1. Materials

Mature maize (*Z. mays* var. *indurata* L. cv. Suwon-19; yellow flint type) was harvested at commercial maturity from a commercial farm in the Sangju region of Korea. Before the kernels were separated from the cob, they were sun dried until the moisture content reached 13 g/100 g. Only healthy kernels that were uniform in size were used for roasting. The weight of 100-kernels was approximately 35 g. Folin-Ciocalteu reagent was purchased from Junsei Chemical Co. (Tokyo, Japan), and chlorogenic acid and 2,2-diphenyl-1-picrylhydrazyl (DPPH) were purchased from Sigma–Aldrich Chemical Co. (St. Louis, MO, USA). All other chemicals used for the analyses were of high purity grade.

2.2. Experimental design and statistical analysis

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 160 °C to 240 °C and from 10 min to 50 min, respectively. These ranges in roasting temperature and time reflect the ranges commonly used in conventional roasting. Each independent variable had five levels: −2, −1, 0, +1 and +2. Ten combinations were randomly chosen according to a CCD configuration for 2 independent variables. The experimental design of the coded and actual levels of the variables is shown in Table 1. The dependent variables (responses, Y) were yield, content of free sugar, content of phenolic compounds, DPPH radical scavenging activity, and score of overall preference of

the beverage prepared from the roasted maize. The responses were related to the independent variables by a second-degree polynomial using the equation below.

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

In this equation, β_0 is constant, β_1 and β_2 are linear coefficients, β_{11} and β_{22} are quadratic coefficients, and β_{12} is the interaction coefficient.

Analysis of variance (ANOVA), a partial F-test for individual terms, and an analysis of residuals were performed. ANOVA tables were generated, and the effects and regression coefficients of individual linear, quadratic, and interaction terms were determined. The degrees of significance of all terms in the polynomial were determined statistically by calculating the F-value at a probability (p) of 0.001, 0.01, or 0.05. The regression coefficients were used to make statistical calculations to generate contour maps from the regression models. All statistical analyses were performed using a SAS statistical package (9.1, SAS Institute, Inc., Cary, NC, USA).

2.3. Roasting and extraction processes

Maize kernels (500 g) were poured into the roasting drum of an electric rotary roaster (DR-1, Taehwan Automation Industry Co., Seoul, Korea) and roasted under the conditions selected for each experiment. To ensure that the conditions were stable, the roaster was left to run for 1 h at 250 °C prior to placing the kernels in the roasting drum. The rotary velocity of the roasting drum was constant at 80 rpm. The roasted kernels were cooled to room temperature, packed in nylon/polyethylene bags of 0.08 mm thickness, and kept at 4 °C until use. Immediately before the preparation of the beverages, samples were ground using a mill (J-NCM, Jisico Co., Seoul, Korea) and sieved to size of 0.84 mm. The mixtures of ground kernels (20 g) and distilled water (1500 mL) were introduced in extraction flasks and then extracted in a water bath for 1 h at 80 °C. This ratio of sample and solvent was selected based on preliminary tests, as it ensures effective conditions for good sensory quality. The extract was filtered through filter paper (No. 2, ADVANTEC, Tokyo, Japan) and subjected to tests analyzing the quality indicators. The experiments of beverage preparation, including roasting and extraction processes, were replicated 3 times, and the average values are reported.

2.4. Analysis of extraction yield

A portion (10 mL) of each of the hot water-extracted beverages was transferred into a weighing dish and dried at 105 °C in

Table 1

The central composite experimental design employed for the roasting process of maize kernels.

Experiment number	Temperature (°C, X_1)		Time (min, X_2)	
	Coded	Actual	Coded	Actual
1	1	220	1	40
2	1	220	−1	20
3	−1	180	1	40
4	−1	180	−1	20
5	0	200	0	30
6	0	200	0	30
7	2	240	0	30
8	−2	160	0	30
9	0	200	2	50
10	0	200	−2	10

Table 2

Experimental data for response parameters of maize beverage in relation to roasting conditions.

Experiment number	Yield (g/g)	Free sugar (mg/100 mL)	Phenolic compounds (mg/100 mL)	DPPH radical scavenging activity (%)	Overall preference
1	0.2451	0.00	19.01	62.34	6.91
2	0.1266	3.71	15.47	69.50	4.41
3	0.0919	37.26	9.45	64.49	6.33
4	0.0888	50.68	9.13	46.08	2.91
5	0.1129	12.69	14.12	73.23	6.25
6	0.1107	11.51	13.94	78.26	6.41
7	0.3506	0.00	25.14	80.46	7.33
8	0.0896	71.26	8.37	44.44	2.75
9	0.1530	2.33	15.81	66.12	6.08
10	0.0956	68.08	11.40	43.58	2.58

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