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Investigating the effects of ingredient levels on physical quality properties of cooked hamburger patties using response surface methodology and image processing technology

Hasan Murat Velioğlu [a,*], Serap Duraklı Velioğlu [a], İsmail Hakkı Boyacı [b], İsmail Yılmaz [a], Şefik Kurultay [a]

[a] Namık Kemal University, Agricultural Faculty, Food Engineering Department, Tekirdag 59030, Turkey
[b] Hacettepe University, Engineering Faculty, Food Engineering Department, Ankara 06532, Turkey

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ABSTRACT

A three-factor central composite design was adopted to determine the interactive effects of fat (15–30%), water (10–20%) and textured soy protein (3–9%) content on the shrinkage, fat loss and moisture loss of hamburger patties after cooking. Image processing was used to estimate the shrinkage of hamburger patties. Textured soy protein (TSP) content was found to be the most important factor for minimizing fat and moisture loss. Both fat and water content were found to be significantly effective ($P < 0.05$) in the model for shrinkage and moisture loss in linear form. The changes in shrinkage due to fat, water and TSP content were also in linear form. The model for fat loss was in linear and quadratic form, whereas the model for moisture loss was in full quadratic form. The models for shrinkage, fat loss and moisture loss had the R-square values of 0.954, 0.969 and 0.964, respectively.

1. Introduction

In Turkey, meat and meat products are usually marketed in small butcher shops as steaks and or in ground form. Most people prefer to consume meat and meat products in the latter form. Therefore, in Turkey, a large number of meat products are prepared from ground meat, such as hamburger patties, meatballs, and kebabs (Ulu, 2004, 2006; Yilmaz & Daglioglu, 2003).

Besides quality factors such as colour, taste and texture, the characteristics such as shrinkage, fat loss and moisture loss of hamburger patty are considered as important quality criteria by the consumers. The industrial companies manufacturing hamburger patties for the fast food sector have to pay considerable attention to the standardization of the sizes of hamburger patties. In the fast food sector, the hamburger patties are generally consumed with hamburger buns, and the appearance of patties in the buns is important for the consumers. If the raw and expected sizes of cooked hamburger patties do not meet the required standards, the products are possibly rejected by fast food companies. Hamburger patty shrinkage has never been directly measured. The researchers usually measured the differences between diameter and thickness of the cooked and raw hamburger patties and used these parameters for estimating the shrinkage (Modi, Mahendrakar, Narasimha Rao, & Sachindra, 2003; Serdaroglu & Degirmencioglu, 2004; Serdaroglu, Yildiz-Turp, & Abrodimov, 2005; Ulu, 2006). Measuring the diameter and thickness appeared to be insufficient for the estimation of shrinkage because of the uncertainties in the selection of measurement points.

According to the model presented by Godsalve, Davis, and Gordon (1977) for muscle meat, during cooking, the muscle proteins denature, thereby leading to a decrease in their water holding capacity and shrinkage of the protein network. The shrinking network exerts a mechanical force on the water between the fibres. In the presence of pressure gradients, the excess interstitial water is expelled to the surface of the meat. The expelled fluid is commonly known as cooking loss.

Although there are differences between muscle meat and hamburger patty with regard to the structure and the content, shrinkage is strongly related to the loss of moisture and fat of the meat product. Numbers of researches have been conducted to study the effects of ingredients (Gujral, Kaur, Singh, & Sodhi, 2002; Hsu & Chung, 2000, 2001; Modi et al., 2003; Serdaroglu, 2006; Yilmaz, 2005) and cooking conditions (Hsu & Chung, 1998; Jakobsen & Bertelsen, 2000) on the overall quality of burgers, patties and meatballs. Some researches have also been performed on the shrinkage characteristic of fresh meat (Kong, Tang, Lin, & Rasco, 2008; Zheng, Sun, & Du, 2006).

Computer vision and image processing techniques (IPT) help in the accurate, fast and objective quality determination of important characteristics of food products (Aguirre, Frias, Barry-Ryan, & Grogan, 2009; Briones & Aguilera, 2005; Brosnan & Sun, 2004;

* Corresponding author. Tel.: +90 282 2931442; fax: +90 282 2931480.
E-mail address: mvelioglu@nku.edu.tr (H.M. Velioğlu).

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Johansen, Laugesen, Janhøj, Ipsen, & Frøst, 2008; Kilic, Boyaci, Koksel, & Kusmenoglu, 2007). As an objective, fast and non-destructive tool, image processing has been increasingly applied to determine the different qualitative properties of fresh meat (Barbera & Tassone, 2006; Jackman, Sun, Du, Allen, & Downey, 2008; Tan, 2004) and a wide range of meat products (Du & Sun, 2006a, 2006b; Mendoza et al., 2009; Valous, Mendoza, Sun, & Allen, 2009). IPT could also be automatically implemented for the measurement of the shrinkage of hamburger patty.

Response surface methodology (RSM), a powerful mathematical and statistical technique for testing multiple process variables and their interactive and quadratic effects, is useful in solving multivariable equations obtained from experiments simultaneously. In the analysis of interactions between the responses (dependent variables) and the factors (independent variables) of experiment, this technique provides an advantage of the reduction in the number of experiments as compared to the full experimental design (Ghodke, Ananthanarayan, & Rodrigues, 2009; Murphy, Gilroy, Kerry, Buckley, & Kerry, 2004; Shih, Kuo, Hsieh, Kao, & Hsieh, 2008; Tiwari, Muthukumarappan, O'Donnell, & Cullen, 2008).

RSM has been used for the simultaneous analysis of the effects of process parameters in fresh meat processing (Jakobsen & Bertelsen, 2000) and also in some meat products (Desmond, Troy, & Buckley, 1998; Hsu & Chung, 2000, 2001; Hsu & Yu, 1999). According to these researches, RSM can help in predicting the combined effects of ingredients on shrinkage, fat loss and moisture loss of hamburger patties.

The aim of the present work is to determine the combined effect of fat, water and TSP content on shrinkage, fat loss and moisture loss of hamburger patties and to develop mathematical models to find the optimum percentages of these ingredients for these criteria by using RSM and IPT. These models will provide a new approach for proposing optimum levels for water, fat and TSP addition in order to produce standard products preferred by the consumers.

Table 1
Experimental range levels of three independent variables in terms of actual values.

Variables	Symbols	Coded variable levels				
		−α (−1.682)	−1	0	1	+α (1.682)
Fat (%)	X_1	9.9	15.0	22.5	30.0	35.1
Water (%)	X_2	6.6	10.0	15.0	20.0	23.4
TSP (%)	X_3	1.0	3.0	6.0	9.0	11.0

2. Materials and methods

2.1. Experimental design

In this study, effects of fat, water and TSP contents on shrinkage, fat loss and moisture loss of hamburger patties after cooking were investigated using RSM. Experimental range levels of the three independent variables in terms of the actual values are given in Table 1 with coded variable levels. Twenty runs were performed in a completely random order according to the central composite design with three factors, six replicates at the center points and a single run for each of the other combinations. Duplicate experiments were carried out at all design points. The experimental design is given in Table 2.

Beef meat, fat, spices and additives were supplied from local market. Hamburger patty samples were produced in 3 kg batches for every run. Beef meat (moisture 74%, fat 10%) was ground, and fat (fat 90%, moisture 8%), water, TSP (protein 70%, moisture 3%) and spices (cumin 0.4%, red pepper 0.4%, black pepper 0.3%, onion powder 0.2%, allspice 0.2% and salt 1.5%) were separately added in order to adjust the percentages of the ingredients according to experimental design for each 3 kg batch. Each portion was kneaded for 15 min using hands to obtain homogeneous dough. The dough was stored in a cold room (+4 °C) for 1 day. The dough in each batch was shaped into hamburger patties by using manual hamburger patty forming machine. The prepared hamburger patties had the following dimensions: a diameter of 6 cm, a height of 1.5 cm and an approximate weight of 50–60 g. Hamburger patties were cooked in a pre-heated Teflon® coated pan according to a standard protocol of 3 min, 1 min and then 15 s on each side to achieve an internal end-point temperature of 72 °C (measured using a thermocouple). The flow chart for the production of hamburger patty is shown in Fig. 1.

2.2. Image acquisition

The raw and cooked hamburger patties were placed directly on a flatbed scanner (HP Scanjet 3400C) that was placed in a closed

Table 2
Central composite design arrangement and experimental responses.

Run order	Fat (%)	Water (%)	TSP (%)	Meat (%)	Spices (%)	Shrinkage (%)	Moisture loss (%)	Fat loss (%)
1	15	20	9	53	3	34.70	9.20	8.35
2	30	10	3	54	3	52.16	15.35	27.66
3	30	10	9	48	3	42.70	8.10	14.67
4[a]	22.5	15	6	53.5	3	41.68	14.98	30.76
5[a]	22.5	15	6	53.5	3	42.85	15.01	28.75
6	22.5	6.5	6	62	3	40.89	10.01	24.54
7	15	20	3	59	3	44.67	18.66	23.18
8[a]	22.5	15	6	53.5	3	46.20	14.67	30.43
9	15	10	3	69	3	35.87	14.49	22.96
10	15	10	9	63	3	31.42	8.14	10.41
11	35	15	6	41	3	52.53	14.39	28.98
12[a]	22.5	15	6	53.5	3	43.58	13.34	30.63
13	22.5	15	11	48.5	3	38.21	5.45	3.25
14	22.5	15	1	58.5	3	49.24	21.01	28.27
15[a]	22.5	15	6	53.5	3	43.58	14.66	29.10
16	30	20	9	38	3	49.01	10.88	14.43
17[a]	22.5	15	6	53.5	3	43.58	15.44	29.60
18	22.5	23.5	6	45	3	48.51	18.75	27.54
19	10	15	6	66	3	30.73	13.48	17.80
20	30	20	3	44	3	55.23	21.62	31.47

[a] Central points of experimental design.