Modelling with response surface methodology of the effects of egg yolk, egg white and sodium carbonate on some textural properties of beef patties

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Abstract This study was accomplished to determine the effects of egg yolk, egg white and sodium carbonate on textural properties of beef patties by using Central Composite Design of Response Surface Methodology. Meat patties were prepared using beef, lamb tail fat and spices. Effects of addition of egg yolk powder (0–1%), egg white powder (0–1%) and sodium carbonate (0–1%) on textural properties were studied by using a texture analyzer. The TPA and cutting force tests were measured in the samples. Effects of sodium carbonate were found to be significant ($P < 0.01$) on springiness, hardness and cohesiveness values of beef patties. However, effects of egg white and egg yolk on the textural parameters were not found significant ($P > 0.05$). The levels of sodium carbonate up to 0.72% improved the textural properties of beef patties.

Keywords Beef patties · Sodium carbonate · Egg white · Egg yolk · Texture

Introduction

Meat patties are minced meat product that is manufactured from beef, poultry or some other animal muscles with fat. Textural properties of minced meat products are related to physicochemical and technological characteristic of ingredients. Non-meat proteins and additives play an important role in the modification of textural characteristic of meat products (Berry 1994; Gujral et al. 2002; Sarıçoban et al. 2009). The type and the amount of non-meat ingredients in formulations of meat products are the most important factors for product quality, technological properties and health (Talukder and Sharma 2010; Verma and Banerjee 2010).

Egg products can be widely used in foods and can improve gel forming capability, water holding capacity, emulsification and nutrition properties of foods (Linden and Lorient 1999; Kiosseoglou 2003). Technological properties of egg products are more important than nutritional properties for using in meat products. They can affect textural properties of meat patties (Gujral et al. 2002).

Refined sodium carbonate is used for pH arrangement in order to improving textural properties of products. Its solution in water is clear, colourless and alkaline. The objective of this study was to determine effects of sodium carbonate, egg white and egg yolk on textural properties of beef patties using a central composite design.

Materials and methods

Beef boneless rounds and lamb tail fat were obtained from a local market. Egg white and egg yolk powders were

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Table 1 Central composite design of three independent variables

Run order	Sodium carbonate (%)	Egg yolk powder (%)	Egg white powder (%)
1	0	0	0
2	0	0	1
3	0	1	0
4	0	1	1
5	1	0	0
6	1	0	1
7	1	1	0
8	1	1	1
9	0	0.5	0.5
10	1	0.5	0.5
11	0.5	0	0.5
12	0.5	1	0.5
13	0.5	0.5	0
14	0.5	0.5	1
15	0.5	0.5	0.5
16	0.5	0.5	0.5

obtained from AB foods (A.B Gıda San. ve Tic. A.Ş., Istanbul Turkey).

Beef patty preparation

Meat and lamb tail fat pieces (~3 cm³ in size) were mixed and standardized to 15% fat. This mixture was minced in a grinder (Cem, İstanbul, Turkey). 1.5% salt, 3% bread crumb, 1% red pepper, 1% black pepper, 1% cumin, 0.5% thyme, and 5% onion were added to the minced meat and minced an additional two times in a grinder (Cem, Turkey). This formulation was mixed by hand and divided into 16 equal parts. Egg white, egg yolk, and sodium carbonate were added to each part as shown in Table 1. Each formulation was then kneaded for approximately 10 min by hand to obtain a uniform meatball dough. Then, each piece of dough was shaped manually into approximately 1.3 cm thick and 6 cm diameter circular-shaped beef patties. The beef patties were cooked on a preheated electric grill (Tefal Largon, Turkey) for approximately 15 min at 180 °C and were flipped every 3 min.

Determination of textural properties

The instrumental textural analyses of the samples were made using a texture analyser (TA-XT Plus Texture Analyzer, UK). Texture profile analysis (TPA) and cutting tests were made using 50 kg and 5 kg load cells,

respectively. Spherical probes (P/1S) with 1 inch diameter for TPA and, the blade set (HDP/BS) and heavy duty platform (HDP/90) for cutting tests were attached to the testing machine. Hardness, springiness, cohesiveness and chewiness values were determined in TPA. Cutting energy (J), cutting force (N) and cutting work (Ns) values were determined in cutting tests. Two beef patties were evaluated by 2 cycles reading in each replication.

Statistical analysis

The experimental design and statistical analysis were performed using JMP 4 Software (SAS Institute Inc.). The experiments were based on a central composite design with a total of 16 combinations, including two replicates of the centre point were carried out in random order.

Two replicates were performed for this study. The variance for each factor assessed was partitioned into linear, quadratic and interactive components and was represented using a second order polynomial equation. The equation is:

$$Y = \beta_0 + \sum_{i=1}^k \beta_i x_i + \sum_{i=1}^k \beta_{ii} x_i^2 + \sum_{\substack{li=1 \\ i < j}}^k \sum_{j=1}^k \beta_{ij} x_i x_j$$

where Y is the estimated response, β_0 , β_i , β_{ii} , and β_{ij} are constant coefficients, k is the number of factor variables, and X_i , X_{ii} , and X_{ij} represent the linear, quadratic and interactive effects of the independent variables (sodium carbonate, egg white and egg yolk), respectively. The analysis was performed using uncoded units.

Results and discussion

The linear effects of sodium carbonate on the texture profile analyses with the exception of chewiness were found to be significant ($p < 0.01$; Table 2).

Springiness

The linear effects of sodium carbonate on springiness values were found to be significant ($p < 0.01$; Table 2). The increasing sodium carbonate levels increased springiness values (Fig. 1). Springiness is relating to the degree of recovery after the deforming force is removed (Monacol et al. 2008). Therefore, increasing springiness values might be attributed to gel formation of muscle proteins. These effects of the sodium carbonate may be related to its alkaline character. The physicochemical properties of proteins can have an effect on textural

Table 2 Analysis of variance of the effects of sodium carbonate, egg white and egg yolk on textural properties of beef patties

Sources of Variation	DF	Chewiness F-value	Springiness F-value	Hardness (N) F-value	Cohesiveness F-value	Cutting force (N) F-value	Cutting energy (J) F-value	Cutting work (Ns) F-value
X ₁ (Sodium carbonate)	1	4.1870	45.2607 **	11.639 **	61.1992 **	0.464	0.2137	0.190
X ₂ (Egg yolk)	1	0.0036	0.5786	0.019	0.2311	0.164	0.1091	0.119
X ₃ (Egg white)	1	0.1909	0.0181	0.189	0.1017	0.065	0.3000	0.283
X ₁ *X ₁	1	0.0779	2.2452	0.019	3.7335	0.043	0.1979	0.205
X ₂ *X ₁	1	0.5997	0.5528	0.403	0.0000	0.045	0.0857	0.079
X ₂ *X ₂	1	0.2379	0.3717	0.056	0.6266	0.150	0.1416	0.142
X ₃ *X ₁	1	0.1243	0.5913	0.029	0.3211	0.227	0.0576	0.051
X ₃ *X ₂	1	0.0490	0.2751	0.008	0.0144	0.011	0.0089	0.011
X ₃ *X ₃	1	4.1870	0.2228	0.009	0.0492	0.208	0.3221	0.328
Lack of fit	5	0.1817	0.1101	0.134	0.1004	0.097	0.0879	0.091
C. total	31							

** $P < 0.01$ significance level, *DF* degrees of freedom

Fig. 1 Effects of sodium carbonate and egg white or egg yolk on texture values of beef patties

properties of meat products (Zorba and Kurt 2006). The changes in the muscle proteins with pH and thermal process led to gel formation, increasing the slicing ability of the meat products (Kerry et al. 2002).

Hardness

The linear effects of sodium carbonate on hardness values were found to be significant ($p < 0.01$; Table 2). As shown in Fig. 1, increasing sodium carbonate decreased hardness values. It is known as sodium carbonate is used for pH arrangement. The effects of sodium carbonate on hardness values can be attributed to changes in pH. Changes in pH value of muscle proteins improved the textural quality and water holding capability of meat products (Gökalp et al. 1999). The changes in pH can affect the solubility of proteins (Zorba et al. 1993a, 1993b). Some components can be retained inside the protein matrix during gel formation (Ziegler and Acton 1984; Ker and Toledo 1992). Myofibrillar proteins play an important role in gel formation which contributes to the desirable texture and fat-water stabilisation in meat products (Ziegler and Acton 1984). Thus it can be said that thermally induced gel formation and retained moisture and fat inside the protein matrix can decrease hardness values.

Cohesiveness

The linear effects of sodium carbonate on cohesiveness values were found to be significant ($p < 0.01$; Table 2). As shown in Fig. 1, increasing sodium carbonate increased cohesiveness values. Increasing cohesiveness values may be due to the thermal effect and alkali effect of sodium carbonate on the protein matrix. Protein type and environment pH can affect gel rigidity of meat products (Zorba and Kurt 2006). During thermal process, muscle proteins denature to cross-linked gel network (Smith and Hui 2004). In particular, thermally denatured myofibrillar proteins formed irreversible strong gels that are responsible for the textural and sensory properties (Smith and Hui 2004).

The effects of sodium carbonate, egg white and egg yolk on instrumental textural properties of beef patties are also expressed mathematically in Table 3. These predicted model equations are useful for understanding the effects of studied factors.

Conclusion

Sodium carbonate was effective on the textural properties of beef patties. This effect can be associated with alkaline character of sodium carbonate. Increasing sodium carbonate

Table 3 Predicted model equations for the effects of sodium carbonate (X_1), egg yolk (X_2) and egg white (X_3) on textural properties of beef patties

Parameters	Equations
Chewiness	$Y = 12.903 - 1.429X_1 - 0.042X_2 + 0.305X_3 - 0.380X_1^2 + 0.605X_2X_1 - 0.664X_2^2 + 0.275X_3X_1 + 0.173X_3X_2 + 0.007X_3^2$
Springiness	$Y = 0.830 + 0.035X_1 + 0.004X_2 + 0.001X_3 - 0.015X_1^2 + 0.004X_2X_1 - 0.006X_2^2 + 0.004X_3X_1 + 0.003X_3X_2 + 0.005X_3^2$
Hardness (N)	$Y = 22.036 - 4.524X_1 - 0.180X_2 + 0.577X_3 + 0.360X_1^2 + 0.941X_2X_1 - 0.610X_2^2 + 0.254X_3X_1 + 0.136X_3X_2 - 0.242X_3^2$
Cohesiveness	$Y = 0.714 + 0.035X_1 - 0.002X_2 - 0.001X_3 - 0.017X_1^2 + 0.00002X_2X_1 - 0.007X_2^2 + 0.003X_3X_1 + 0.001X_3X_2 + 0.002X_3^2$
Cutting force (N)	$Y = 43.672 + 1.764X_1 - 1.049X_2 + 0.660X_3 - 1.044X_1^2 + 0.613X_2X_1 + 1.956X_2^2 + 1.380X_3X_1 - 0.296X_3X_2 - 2.300X_3^2$
Cutting energy (J)	$Y = 0.648 + 0.01682X_1 - 0.012X_2 + 0.019X_3 - 0.030X_1^2 + 0.011X_2X_1 + 0.026X_2^2 + 0.009X_3X_1 - 0.004X_3X_2 - 0.039X_3^2$
Cutting work (Ns)	$Y = 323.498 + 7.601X_1 - 6.012X_2 + 9.287X_3 - 15.379X_1^2 + 5.4865X_2X_1 + 12.829X_2^2 + 4.424X_3X_1 - 2.061X_3X_2 - 19.470X_3^2$

levels up to 0.72% improved the textural properties of beef patties. However, egg white and egg yolk powders were not effective on textural properties of beef patties.

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