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Improving low fat meatball characteristics by adding whey powder

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Abstract

In this study whey powder (WP) at levels of 0%, 2% and 4% was added to beef meatballs formulated with 5%, 10% and 20% fat levels. Raw and cooked meatballs were analyzed for protein, fat, moisture, ash and pH. Meatballs were evaluated for cooking characteristics, juiciness, colour parameters (L^*, a^*, b^*) and sensory properties. Addition of WP did not affect fat and protein contents of meatballs. Addition of 2% or 4% WP significantly increased cooking yield regardless of the fat level. Both fat level and WP level significantly affected fat retention values of meatballs. Incorporating WP had no effect on meatball juiciness. Addition of WP increased fat and moisture retention of meatballs. Twenty percent fat resulted in higher L^* and lower a^* values. Adding WP resulted in higher L^* values but WP had no effect on a^* and b^* values. WP had no detrimental effect on sensory properties.
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Keywords: Meatball; Whey; Ground meat; Fat replacers; Low fat meat products

1. Introduction

Meat products are usually marketed in small butcher shops as steaks and/or in the ground form in Turkey and most of the people prefer consuming meat in the ground form (Yılmaz & Dağlıoğlu, 2003). Fat is an important constituent in ground meat products, it contributes to texture and flavour. The major problem in acceptability of low-fat processed meat products is the decline in palatability with fat reduction (Khalil, 2000; Serdaroğlu & Sapancı-Özsümer, 2003; Yılmaz & Dağlıoğlu, 2003). Extensive research has been carried out on fat replacers to improve the quality of reduced fat ground meat products (Anderson & Berry, 2001; Desmond, Troy, & Buckley, 1998). Dairy ingredients have been used as fillers and binders in comminuted meat products to improve texture and sensory properties and minimize cooking losses (Hung & Zayas, 1992). Whey is a by-product of cheese and casein manufacture and contains approximately 20% of the original milk protein (McIntosch et al., 1998). Extensive research has been done on the using whey protein concentrate in emulsion type meat products such as frankfurters and bologna sausages (Hung & Zayas, 1992; Lyons, Kerry, Morisey, & Buckley, 1999; Serdaroğlu & Sapancı-Özsümer, 2003; Serdaroğlu & Deniz, 2004; Yetim, Müller, & Eber, 2001). Turkish style meatballs (koefte) are produced mainly from ground meat (beef and lamb), fat (beef fat and/or lamb tallow fat), various spices and moistened bread (Serdaroğlu & Değirmencioğlu, 2004; Yılmaz, 2004). Moistened bread and rusk are the main fillers and binders in formulations of meatballs (koefte). This study was designed to determine whether whey powder (2% or 4%) added in the formulation of Turkish type meatballs (koefte) prepared with different levels of beef fat (5%, 10%, 20%) would help to maintain acceptability.

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2. Material and methods

2.1. Meatball preparation

Beef as boneless rounds was obtained from the Pınar Meat Company Inc., Izmir, Turkey. All subcutaneous fat and intermuscular fat was removed from the muscles and used as the fat source. Lean and fat were ground in a 3-mm plate grinder. The experiment was a 3×3 factorial design with three levels of fat (5%,10%, 20%) and three levels of whey powder (WP) (0%, 2%, 4%). WP (13% protein, demineralized) was provided by the from Pınar Dairy Co, Izmir. Additional ingredients were as follows; 2% salt, 1.8% spice mix (black pepper, red pepper, cumin), 1.5% onion rind. Five kg batches of appropriate amounts of each formulation were mixed and processed into meatballs (1.5 cm thick and 100 mm diameter) by using a metal shaper. Meatballs were placed on plastic trays and wrapped with polyethylene film and frozen at −18 °C until further analysis.

2.2. Proximate analysis

Moisture and ash content and pH of each meatball were measured using AOAC (1990) procedures. Fat content was determined by using a chloroform–methanol extraction method according to Flynn and Bramblett (1975). Protein content was determined according to Anon, 1979. Analyses were done on five meatballs.

2.3. Cooking procedure and cooking measurements

Meatballs were thawed at 4 °C overnight and were cooked in a preheated electric grill for 4 min each side. All cooking measurements were done on five replicates per treatment. Percent cooking yield was determined by calculating weight differences for samples before and after cooking. Cooking yield and fat retention were calculated according to Murphy, Criner, and Grey (1975):

$$\text{Cooking yield}(\%) = \frac{(\text{Cooked meatball weight})}{(\text{Uncooked meatball weight})} \times 100,$$

$$\text{Fat retention}(\%) = \left[\frac{(\text{Cooked weight}) \times (\%\ \text{fat in cooked meatball})}{(\text{Raw weight}) \times (\%\ \text{fat in raw meatball})}\right] \times 100.$$

Moisture retention value represents the amount of moisture retained in the cooked product per 100 g of sample and was determined according to an equation by El-Magoli, Laroia, and Hansen (1996).

$$\text{Moisture retention}(\%) = \frac{(\%\ \text{Yield} \times \%\ \text{moisture in cooked meatball})}{100}.$$

Juiciness measurement was done according to Gujral, Kaur, Singh, and Sodhi (2002) with modifications. A grilled meatball sample (5 g) was taken from the center and was cut into 3 mm pieces with a knife. A sample (1 g) was placed between a pair of pre-weighed Whatman (No. 40) filter paper covered with aluminium foil and pressed for 1 min by 10 kg force. The residue was removed and the filter paper was weighed, the extracted juice in percent was determined as follows:

$$\text{Juiciness}\% = (\text{Wt. of filter paper after pressing} - \text{Wt. of filter paper before pressing} / \text{Wt. of sample}) \times 100.$$

2.4. Colour

Colour was measured on five raw meatballs per formulation using a Minolta CR-300 (Minolta Co. Osaka Japan) spectrocolorimeter equipped with a light source illuminant D65 (10° standard observer). Colour coordinate values (L^*, a^*, b^*) were recorded. Before each measurement, the apparatus was standardized against a white plate.

2.5. Sensory evaluation

Meatballs were served warm to a six-membered trained panel (graduate students and staff of Ege University Food Engineering Department) for sensory attributes of appearance, texture, juiciness and flavour. An eight point scale was used where, 8 = extremely desirable, extremely tender, juicy, intense in beef flavour, acceptable and 1 = denoted extremely undesirable, extremely tough, dry, devoid of beef flavour, unacceptable. Water and bread served for cleaning the mouth between samples.

2.6. Statistical analysis

The trial was performed twice. ANOVA for Response Surface 2FI Model was performed using Design Expert- 6, Release 6.0. Stat-Ease Inc. 2003. For proximate composition to obtain confidence intervals means were compared by using the least significance difference (LSD) multiple range test at 95% confidence level (Steel & Torrie, 1980).

3. Results and discussion

3.1. Proximate composition

Mean percent moisture, protein, fat, ash contents and pH values of raw and cooked meatballs are given in Table 1. Moisture and protein percentages of raw and

Table 1
Chemical composition and cooking properties of meatballs

	5[A]/0[B]	5/2	5/4	10/0	10/2	0/4	20/0	20/2	20/4
Raw meatballs									
Moisture (%)	70.7a	69.5a	68.3ab	68.5ab	66.3b	84.1c	61.5d	59.1d	58.7e
Protein (%)	18.2a	18.7a	18.4a	17.3ab	17.7ab	17.2ab	15.9b	16.1b	16.2b
Fat (%)	5.9a	6.3a	6.0a	12.3b	11.2b	11.8b	20.9c	21.1c	21.5c
Ash (%)	1.1a	1.9b	2.4c	1.3a	2.1b	2.9c	1.5a	2.2b	2.9c
pH	6.1	6.0	6.1	5.9	6.0	6.0	5.9	6.1	6.1
Cooked meatballs									
Moisture (%)	64.7a	63.3a	64.1a	62.9ab	63.8a	64.1a	56.1c	57.5c	58.4b
Protein (%)	19.8a	19.1a	20.1a	16.9b	16.5b	16.1b	14.2c	13.9c	14.1c
Fat (%)	6.3a	7.1a	6.4a	13.6b	12.0b	13.4b	22.8c	22.2c	23.8c
Ash (%)	2.6	2.8	2.7	2.5	2.5	2.8	2.7	2.5	2.7
pH	6.5	6.5	6.3	6.3	6.1	6.3	6.2	6.1	6.2

(a–e): Means ($n = 5$) followed by a different letter are significantly different ($p < 0.05$).
[A] Fat level.
[B] Whey powder level.

cooked meatballs were affected by fat levels as expected ($p < 0.05$). Addition of WP slightly altered the moisture content of raw meatballs due to the increment in dry matter in the meatball formulation ($p < 0.05$). Similar results were obtained by Desmond et al. (1998). WP had no effect on fat and protein contents of the raw and cooked meatballs. This is not a surprising result since WP, which was used in this research, had quite a low protein content (13%). The protein and fat content of all meatballs were within the limits of the Turkish Uncooked Meatball Standard (TSE, 1992). The ash contents of raw meatballs increased slightly with the addition of WP ($p < 0.05$). Four percent WP almost doubled the ash content when compared with that of the control (none added) at each fat level. Fat content of the raw and cooked meatballs varied according to formulation as expected. Results clearly showed that cooking increased the fat proportion and decreased moisture percentage in all formulations. The water that was not bound tightly by the proteins may have been released during cooking. pH values of uncooked and cooked meatballs were not significantly different among treatments. Cooking slightly increased pH in all treatments.

3.2. Cooking measurements

Table 2 shows the regression coefficients for cooking properties of meatballs prepared with different levels of fat and whey powder. Cooking loss occurs by loss of fat and evaporation of moisture. Analyses of variance indicated that the regression model derived for cooking yield was significant. Addition of 2% or 4% WP significantly increased cooking yield regardless of the fat level ($p < 0.05$). The reduced cook loss in WP added samples maybe attributed to the water holding and fat binding capacities of whey proteins (El-Magoli et al., 1996). Hale, Carpenter, and Walsh (2002) found that patties with added textured WP had lower cooking losses than all beef patties. The lowest cooking yield in control meatballs (no added WP) might be attributed to the excessive fat separation and water release during cooking. In control samples increasing the fat level from 5% to 10% decreased cooking yield however similar cooking yields were observed at 5% and 20% fat levels (Fig. 1).

Analysis of variance indicated that the regression model for fat retention was highly significant (Table 2). Both fat level and WP level significantly affected

Table 2
Regression coefficients and analysis of variance of regression models of cooking properties

	Cooking yield (%)		Fat retention (%)		Moisture retention (%)		Juiciness (%)	
	RC	SE	RC	SE	RC	SE	RC	SE
Intercept	82.34***	0.83	88.57***	0.26	50.52***	0.32	17.61**	0.68
Fat	−2.26***	0.99	−1.57***	0.31	−2.71**	0.38	−3.91**	0.81
WP	2.69***	1.02	3.59***	0.32	1.19**	0.39	1.09ns	0.84
Fat × WP	−0.55ns	1.22	1.74***	0.38	−0.88ns	0.46	0.1ns	1.00
r^2	0.835		0.970		0.929		0.831	

RC, regression coefficient; SE, standard error; WP, whey popwder; ns, non-significant.
** Significant at 0.05 level.
*** Significant at 0.001 level.

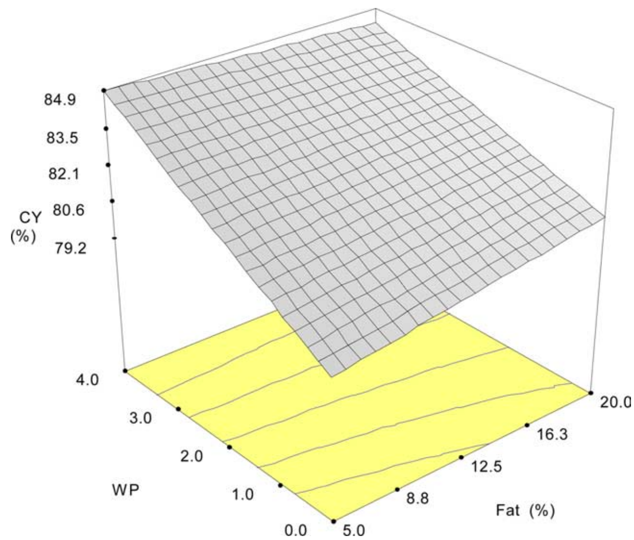

Fig. 1. Effect of fat and whey powder (WP) levels on cooking yield (CY) of meatballs.

fat retention values of meatballs. In control samples increasing fat level resulted in lower fat retention values. The lowest fat retention was found in meatballs formulated with 20% fat and no WP (Fig. 2). This result is in good agreement with that obtained by Mansour and Khalil (1999) who observed that low fat patties retained more fat during cooking than that higher fat samples. Tornberg, Olsson, and Persson (1989) concluded that the dense meat protein matrix of low fat ground beef prevented fat migration. There was significant interaction between fat level and WP level for fat retention ($p < 0.05$). WP had no effect on fat retention at 5% fat level, however adding WP increased fat retention at 10% and 20% fat levels, suggesting that the meat proteins were only capable of binding and retaining fat and water at a fat level between 5% and 10%.

Decreasing fat in meatball formulations resulted in higher moisture retention and juiciness ($p < 0.05$), meatballs formulated with 20% fat had lower moisture retention values than meatballs formulated with 5% and 10% fat (Fig. 3). Similar to our results Gujral et al. (2002) reported that reducing the fat content from 15% to 0% increased meatball juiciness. WP significantly increased moisture retention values of meatballs at each fat level. Similar results were obtained in our previous research, which was focused on using corn flour in Turkish type meatballs (Serdaroğlu & Değirmencioğlu, 2004). The regression model developed for juiciness was significant (Table 2) . Increasing fat level resulted in lower juiciness values in meatballs (Fig. 4). Pietrasik and Duda (2000) reported that, as the fat content of processed meat products is gradually reduced while the water content is increased the products water binding capacity becomes the critical issue in production. An inverse relationship between the fat level and juiciness values (amount of water released) found in our work is similar to previous reports (Hughes, Cofrades, & Troy, 1997; Pietrasik & Duda, 2000). Incorporating WP had no effect on meatball juiciness ($p > 0.05$). Product formulation and processing methodology are key determinants of fat loss and weight loss during cooking of products such as sausages and burgers (Sheard, Jolley, Hall, & Newman, 1989).

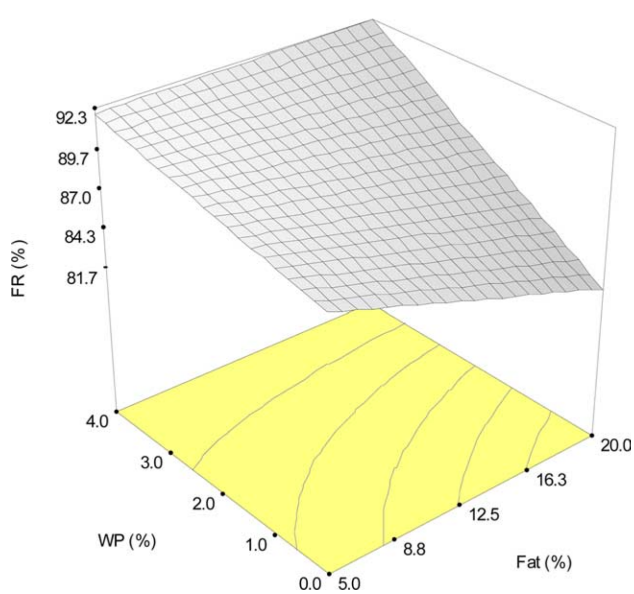

Fig. 2. Effect of fat and whey powder (WP) levels on fat retention (FR) of meatballs.

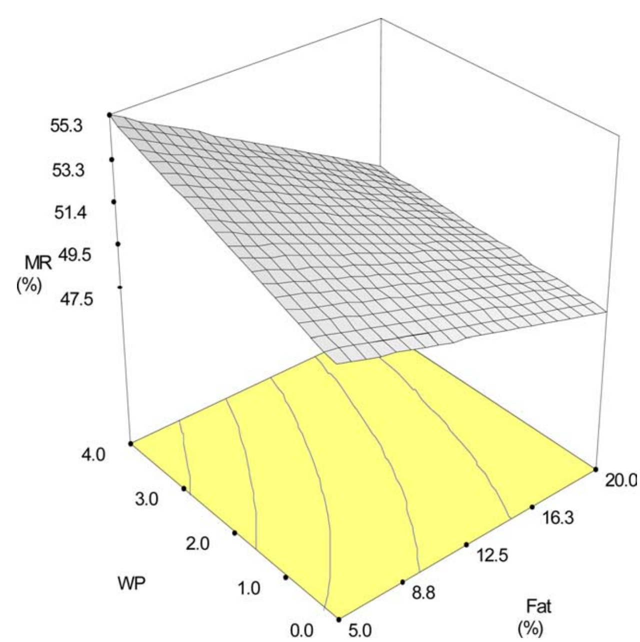

Fig. 3. Effect of fat level and whey powder (WP) level on moisture retention (MR) of meatballs.

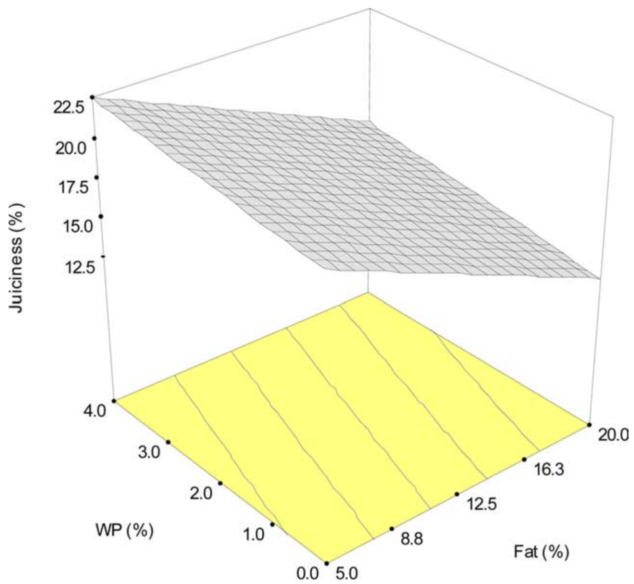

Fig. 4. Effect of fat level and whey powder (WP) level on juiciness of meatballs.

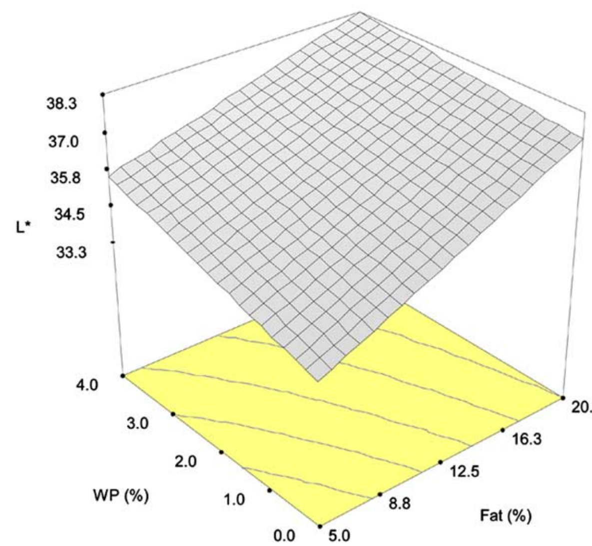

Fig. 5. Effect of fat level and whey powder level on L^* values of meatballs.

3.3. Colour

The colour attributes of cooked meat products arise mainly from the pigmentation of meat with which they are made and the additives which were used in the formulation. Analyses of variance indicated that the regressions for L^* and a^* values were significant (Table 3). The effect of fat level and WP level on colour parameters of meatballs were shown in Figs. 5–7.

In the present study, the fat level and WP level significantly affected L^* values (Table 3) of cooked meatballs ($p < 0.05$). Meatballs formulated with 20% fat were slightly lighter than samples formulated with 5% and 10% fat. Increasing fat level probably resulted in dilution of the myoglobin and because of that, the lowest a^* values (redness) and the highest L^* values (lightness) were obtained for samples with 20% fat. Fat is known to affect the colour parameters of cooked meat products as reported by Hughes et al. (1997). Reducing the fat content from 30% to 5% caused a significant decrease in the lightness of frankfurters (Crehan, Hughes, Troy, & Buckley, 2000). Increasing the fat level in formulation resulted lower a^* values but WP had no effect on the a^* values of meatballs. Neither the fat level nor the WP level affected b^* values of samples ($p > 0.05$).

3.4. Sensory evaluation

Analysis of variance indicated that the regressions for the appearance and juiciness were not significant (Table 4). Sensory evaluation indicated that fat level had some effects on texture, flavour and acceptability scores ($p < 0.05$) (see Figs. 8–12). Decreasing the fat level from 20% to 5% significantly decreased texture scores. Since fat makes an important contribution to the texture of meat products it was anticipated that lowering fat to 5% would decrease texture scores (Table 5). Low-fat comminuted meat products tend

Table 3
Regression coefficients and analysis of variance of regression models of colour parameters

	L^*		a^*		b^*	
	RC	SE	RC	SE	RC	SE
Intercept	36.14***	0.14	5.38***	0.083	11.68ns	0.24
Fat	1.70***	0.17	−0.84***	0.099	−0.16ns	0.29
WP	0.78**	0.17	−0.53ns	0.10	0.08ns	0.30
Fat × WP	−0.36ns	0.20	−5.35	0.12	0.17ns	0.36
r^2	0.963		0.923		0.156	

RC, regression coefficient; SE, standard error; WP, whey powder.
ns, non-significant.
** Significant at 0.05 level.
*** Significant at 0.001 level.

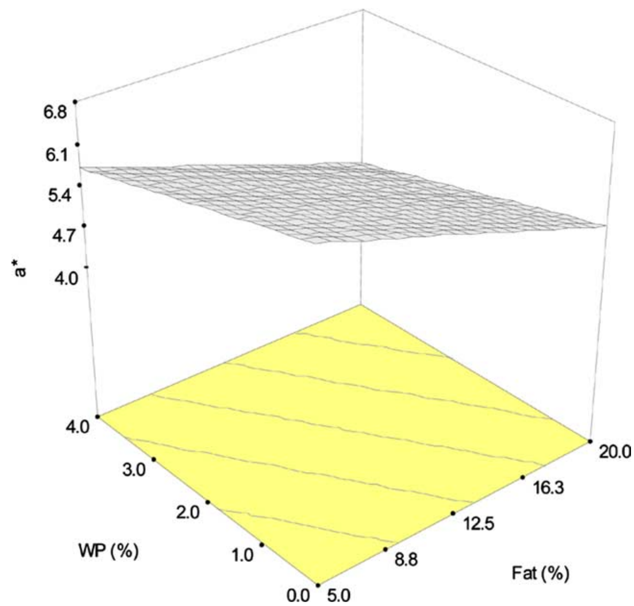

Fig. 6. Effect of fat level and whey powder level on a^* values of meatballs.

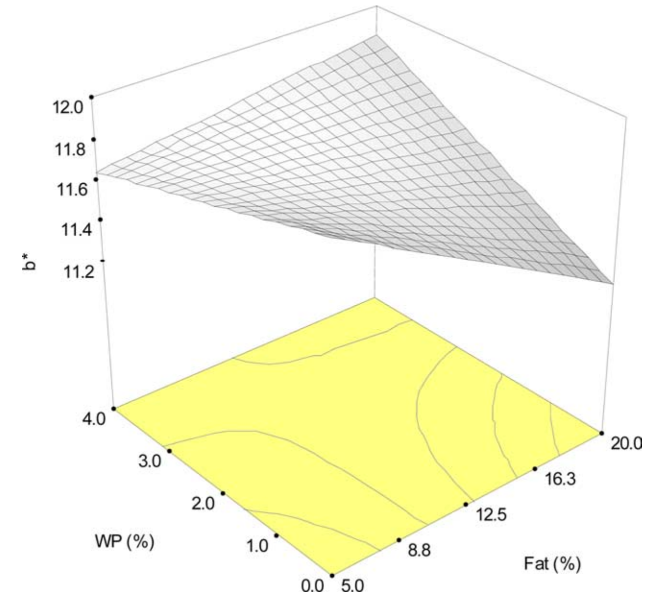

Fig. 7. Effect of fat level and whey powder level on b^* values of meatballs.

Table 4
Regression coefficients and analysis of variance of regression models of sensory properties

	Appearance		Juiciness		Flavour		Texture		Acceptability	
	RC	SE	RC	SE	RC	SE	RC	SE	RC	SE
Intercept	6.52ns	0.070	6.06ns	0.15	6.23ns	0.17	6.24***	0.19	6.80***	0.08
Fat	−0.096ns	0.084	0.50ns	0.18	−0.74**	0.20	1.33**	0.23	0.62**	0.095
WP	−0.055ns	0.086	0.36ns	0.19	−0.032ns	0.20	−0.04ns	0.23	0.18ns	0.098
Fat × WP	0.25ns	0.10	−0.22ns	0.22	−0.14ns	0.24	−0.07ns	0.28	−0.19ns	0.12
r^2	0.625		0.668		0.740		0.827		0.908	

RC, regression coefficients; SE, standard error; WP, whey powder.
ns, non-significant.
** Significant at 0.05 level.
*** Significant at 0.001 level.

Table 5
Sensory scores of meatballs

Sensory properties	5[A]/0[B]	5/2	5/4	10/0	10/2	10/4	20/0	20/2	20/4
Appearance	6.9	6.7	6.5	6.8	6.3	6.2	6.3	6.3	6.8
Juiciness	5.9	5.8	5.9	5.9	6.4	6.2	6.1c	6.1	6.2
Flavour	6.6a	6.9a	6.5a	6.7a	6.9a	6.7a	5.6b	5.3b	5.1b
Texture	4.3a	4.6a	4.8a	6.7b	6.2b	6.0b	7.5c	7.2c	7.5c
Acceptability	6.5b	6.2b	6.5b	6.7b	6.8b	6.8b	7.3c	7.4c	7.4c

(a–c): Different letters in the same row indicate significant differences (8 = extremely desirable, extremely tender, juicy, intense in beef flavour, acceptable and 1 = denoted extremely undesirable, extremely tough, dry, devoid of beef flavour, unacceptable).
[A] Fat level.
[B] Whey powder level.

to be tougher than higher fat products (Ahmed, Miller, Lyon, Vaughters, & Reagan, 1990; Serdaroğlu & Sapancı-Özsümer, 2003). Although contradictory results have been reported in the literature. Marquez, Ahmed, West, and Johnson (1989) reported that reduced fat frankfurters had improved texture.

Fat reduction increased flavour scores of the meatballs probably by influencing the rate of release flavour compounds, meatballs with 5% and 10% fat had higher flavour scores than meatballs with 20% fat. There were no significant differences in acceptability scores of meatballs with 5% and 10% fat, but increasing the fat level to 20% in meatball formulation increased the acceptability scores. Keeping fat within the matrix of meat products during processing is necessary for ensuring sensory quality and acceptability. Panels were not able to detect the addition of WP. Various findings have been reported for the effects of WP on flavour of comminuted meat products. Lyons et al. (1999) demonstrated that increasing concentrations of WP decreased flavour scores by masking spice flavour. Addition of WP to comminuted beef patties has been reported to increase flavour scores (Holland, 1984). In the present research, it is possible that the strong flavour of spices in meatball formulation could have masked whey powder flavour in the product.

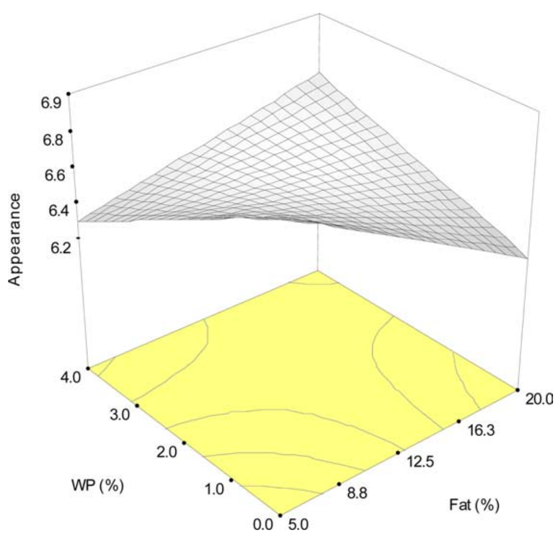

Fig. 8. Effect of fat level and whey powder level on appearance scores of meatballs.

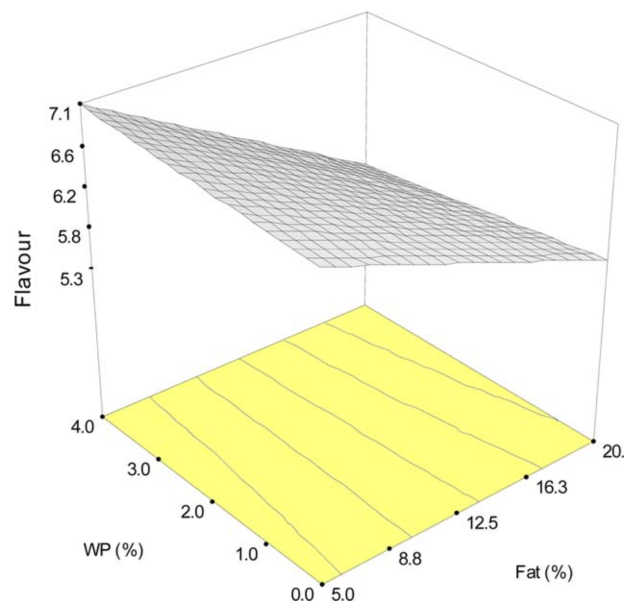

Fig. 10. Effect of fat level and whey powder level on flavour scores of meatballs.

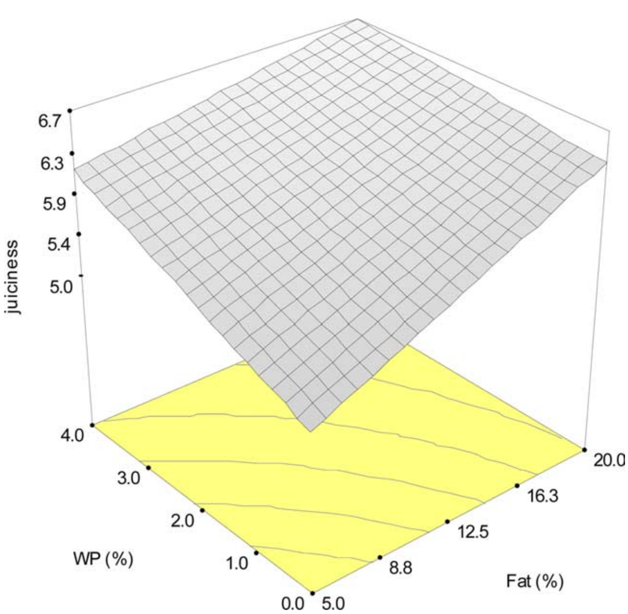

Fig. 9. Effect of fat level and whey powder level on juiciness scores of meatballs.

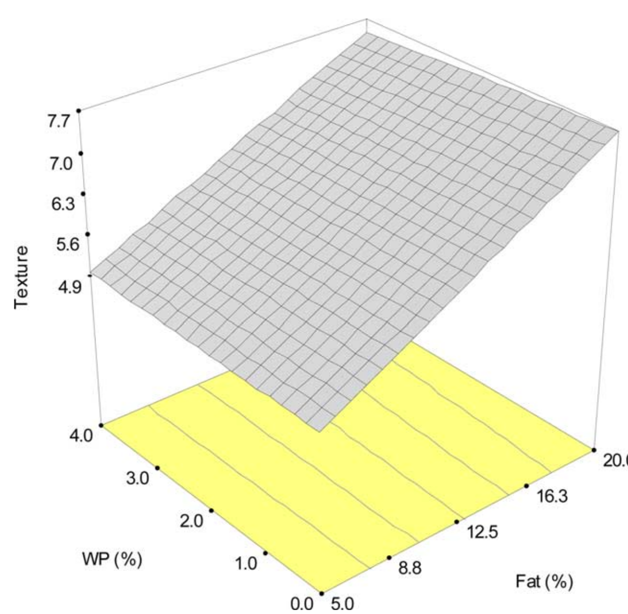

Fig. 11. Effect of fat level and whey powder level on texture scores of meatballs.

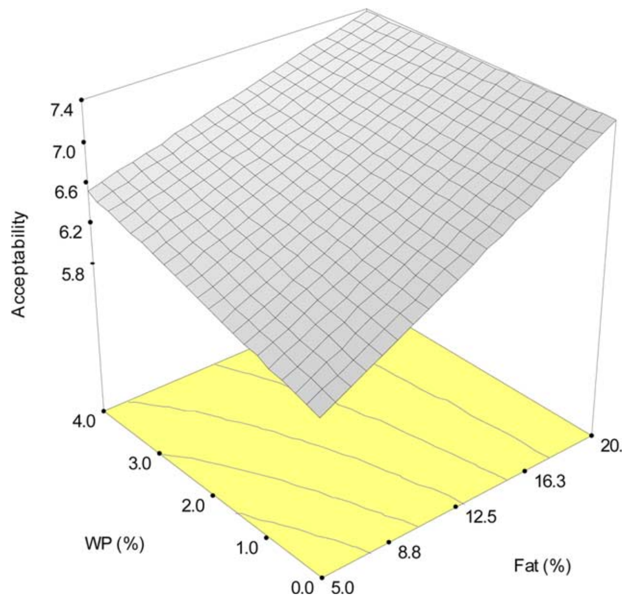

Fig. 12. Effect of fat level and whey powder (WP) level on acceptability scores of meatballs.

4. Conclusions

In summary the results indicate that increasing the fat level in meatball formulation resulted in higher cooking yields, increased fat and moisture retention values and juiciness. Incorporation of whey powder was beneficial in improving cooking characteristics at each fat level. WP containing samples were lighter than the control meatballs. The addition of WP either 2% or 4% did not significantly alter sensory properties of low fat meatballs. Whey powder can be recommended as a filler in traditional Turkish type meatballs to improve cooking characteristics.

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