J. Agr. Sci. Tech. (2015) Vol. 17: 121-132

Improving Textural and Sensory Characteristics of Low-Fat UF Feta Cheese Made with Fat Replacers

H. Rashidi[1*], M. Mazaheri-Tehrani[2], S. M. A. Razavi[2], and M. Ghods-Rohany[1]

ABSTRACT

Saturated fat consumption increases the risk of both coronary and cancer diseases. Therefore, fat reduction in UF-Feta cheese (≈ 45% FDM) is favorable but, unfortunately, it has some negative effects on the texture and sensory characteristics of the cheese. In this research, response surface methodology was employed to study the probably improving effects of WPC80 (0-20 gr kg^{-1}), lecithin (0-2 gr kg^{-1}) and a mixture of xanthan and guar (0-1 gr kg^{-1}) on sensory and instrumental texture characteristics of low-fat UF-Feta cheese made from 6% fat retentate. Lecithin and xanthan-guar had positive and WPC80 had negative effects on hardness, chewiness, and gumminess of the cheeses. Furthermore, results showed lecithin had negative effects on taste, acceptance, and appearance and positive effects on sensory texture. The taste was improved by WPC and xanthan-guar enhanced sensory texture and acceptance scores. Finally, multiple response optimization method was used to determine optimized formula of low-fat cheese (19.47 gr kg^{-1} WPC80, 0.5 gr kg^{-1} xanthan-guar and 0.13 gr kg^{-1} lecithin). A cheese sample produced based on optimized formula and full fat cheese had similar sensory and instrumental texture.

Keywords: Optimization, Response surface methodology.

INTRODUCTION

UF Feta is a soft cheese with 60% moisture, and 1-3% salt that is made using bovine milk with 3.8% fat. Whole milk is ultra filtrated to 35% total solids, filled in the cup and rennet is added. The final product contains 16-22% fat, therefore, considerable fat is absorbed by consumers. UF Feta cheese is the dominant cheese in Iran which does not have ripening period and is consumable 72 hours after production (ISIR, 2002; Ghods Rohani *et al*., 2009).

Overindulging in fat consumption has increased risk of obesity, atherosclerosis, coronary heart diseases, and elevated blood pressure. Therefore, there are executing demands for reduced and low-fat products in the world. Consumers' interest in decreasing fat have caused the development of low-fat foods in the world market (Kavas *et al*., 2004). In spite of consumers' interest, low-fat food products (like cheese) haven't been developed in Iran.

Fat in cheese is the important component playing numerous roles in different aspects of the product quality. It is generally believed that low-fat cheeses are poor in sensory properties and protein dominated structure produces hard and rubbery texture. Off-flavor and bitterness are other defects that appear in low-fat cheeses. As a result, the manufacture of low-fat cheese to create characteristics like those of full-fat cheese is a difficult task (Sipahioglu *et al*., 1999). In recent years, many studies have reported conclusions about the effect of fat reduction on the chemical and textural characteristics of cheeses and attempts have been made to develop new type of low-fat

[1] Department of Food Industry, Institute of Technical and Vocational Higher Education, Jahad-e-Agriculture, Khorasan-e-Razavi Center, Mashhad, Islamic Republic of Iran.
[*]Corresponding author; e-mail: ha_rashidi@yahoo.com
[2] Department of Food Science and Industry, Ferdowsi University of Mashhad, Islamic Republic of Iran.

[DOR: 20.1001.1.16807073.2015.17.1.15.6]

cheeses (Laloy *et al*., 1996; Rudan *et al*., 1999; Tamime *et al*., 1999; Fenelon and Guinee, 1999; Katsiari *et al*., 2002; Volikakis *et al*., 2004; Erdem *et al*., 2005; Lteif *et al*., 2009; Saint-Eve, *et al*., 2009).

Fat replacers are ingredients which are used to replace a part or whole of the natural fat content of a food to reduce the calorie intake by the consumer. Generally, fat replacers increase the moisture content and break down the continuous protein matrix of low-fat cheeses. Furthermore, some of the fat replacers simulate the mouth feel and creaminess of fat in low-fat cheeses. Most of the currently available fat replacers can be divided by composition into three categories: carbohydrate-based, protein-based, and fat-based (Lucca and Tepper, 1994). Furthermore, many of the introduced fat replacers are blends of two or more ingredients, each of which contributes some key complementary quality. Therefore, finding a mixture of fat replacers to improve ideal characteristics of low-fat cheeses have recently been studied (Zisu and Shah, 2005; Totosaus and Guemes-Vera, 2008; Lobato-Calleros *et al*., 2007; Nateghi *et al*., 2012).

The effect of fat reduction on chemical, physical, and sensory properties of UF-Feta cheese is already reported in our previous studies. The cheese samples were manufactured from retentate in different amounts of fat (0, 2, 6, 10, 14, and 18%). A fat reduction from 18 to 14% caused improvement of sensory and texture characteristics of the cheese, but more fat reduction led to progressive loss of quality. Significant sensory and textural defects (poor taste and undesirable texture) were observed in the cheese sample with 6% fat in addition, this cheese sample with 6% fat is categorized as low-fat cheese (based on a standard classification in Iran) Therefore, this cheese sample was selected for further investigation as mentioned in this essay. The combination of applied fat replacers was determined based on manufacturing and evaluation of experimental low-fat cheese samples containing various fat replacers. Furthermore, efficiency of selected fat replacers was investigated in other literatures (Drake *et al*., 1996; Sipahioglu *et al*., 1999; Koca and Metin, 2004; Lobato-Calleros *et al*., 2007; Nateghi *et al*., 2012). In the present study, a mixture of fat replacers including xanthan, guar gum, lecithin and WPC80 were applied to improve the physical and sensory characteristics of low-fat UF Feta cheese with 6% fat.

MATERIALS AND METHODS

Materials

Retentate powder (80% protein, 9% lactose, 1% fat and 7% ash) and cream (30% fat and 35% solids) were obtained from MILEI (Germany) and Gush Co. (Iran), respectively. Rennet (Fromase 2200 TL, Granulate) and DVS starter (Delvo MT54Y DSL, including *Streptococcus thermophillus* and *Lactococcus lactis subdivision cremoris* and lactic) were purchased from DSM (Australia). The used fat replacers were a mixture of guar gum and xanthan (in relation 20:80, Sigma), Lecithin (Sigma) and WPC80 (MILEI, Germany).

Cheese Manufacture

Reconstituted retentate (6% fat and 30% solids) was produced by means of vigorous mixing of water (556 g, 45°C), retentate powder (244 g), cream (200 g), and fat replacers in a laboratory blender (first of all, fat replacers were added to water to ensure complete dissolution), then, the mixture was pasteurized in 65°C for 30 minutes. Starter culture (0.01 g) and rennet (0.03 g) were added to retentate at 35°C and then retentate was filled into 100 g plastic cups. The coagulation stage was completed in an incubator (35°C for 20 minutes). Later, a special paper was placed on the surface of the curd and 2 g salt was laid on the upper surface of the paper. Finally, the cups were covered by cellophane layers. The cheese samples were incubated (27°C for 24 hours) and refrigerated (5°C for 48 hours) according to the ordinary manner in Iran UF

Feta cheese industries (Qods *et al*., 2009). Twenty batches of these cheeses were produced based on combination of fat replacers (samples 1-20 in Table 1) and were analyzed without passing any ripening period.

Instrumental Texture

Texture profile analysis (TPA) parameters were determined by using a texture analyzer (QTS25, CNS FARNEL, UK). A flat cylinder probe with 36 mm of diameter was attached to moving cross head. Cubic samples (20×20×20 cm) were prepared at 5°C and immediately compressed to 50% initial height (10 mm Thickness). The cross head speed was set to 60 mm min^{-1}. and the characteristics of hardness, gumminess, and chewiness were measured in each sample, then, the penetration test was performed. A flat cylinder probe with 3 mm diameter was applied with the penetration speed of 30 mm min^{-1}. The required force for 10 mm penetration within cheese body was measured (Fox *et al*., 2000; Gunasekaran and Mehmet, 2003). Texture values were the mean of three replicates tested at each sampling time.

Sensory Analysis

The sensory evaluation was carried out with scoring test by ten panelists who were the PhD students of food science and technology in Iran. The panelists were familiar with cheese and sensory evaluation and were trained to evaluate the texture, taste, and total acceptance of samples using a score from 1 (unfavorable) to 5 (highly favorable). Washing the mouth was requested from the panelist before test of each 20 g sample (Koca and Metin, 2004).

Statistical Analysis

A three factor central composite design was used. The mixture components consisted of Lct (0-2 g kg^{-1}), XG (0-1 g kg^{-1}) and WPC (0-20 g kg^{-1}) (Table 1). The response surface methodology was carried out to analyze the results. A Duncan multiple range test method was applied for mean comparison ($P< 0.05$). All the statistical analysis were carried out by Design Expert (version, 6.1.2) and MSTATC (version, 1.42) softwares.

RESULTS AND DISSCUSSION

Instrumental Texture Properties

The mean values, regression model coefficient, and ANOVA of the response variables of texture evaluation were determined (Tables 1 and 2). Also, the effect of fat replacers on instrumental texture characteristics has shown (Figures 1a-d). Significant interactions between fat replacers led to increase in hardness, chewiness, and gumminess. Nateghi *et al*. (2012) found that the interaction effect of sodium caseinate with xanthan gum significantly ($P< 0.05$) increased the hardness of the experimental cheeses.

Hardness

The force necessary to attain a given deformation with a maximum force bite when the sample is placed between molars is termed as hardness (Nateghi *et al*., 2012). Results of hardness determination in TPA were inconsistent with penetration test and the correlation was significant ($P< 0.0001$, $r= 0.88$). The cheese sample including a 20 g kg^{-1} WPC80 as a fat replacer had the least hardness. Furthermore, the addition of 1 g kg^{-1} XG or 2 g kg^{-1} Lct resulted in a softer cheese samples than low-fat cheese without fat replacers. It has been frequently reported that the use of different fat replacers has decreased the hardness of cheeses (Bhaskaracharya and Shah, 2001; Romieh *et al*., 2002; Koca and Metin, 2004; Zisu and Shah, 2005). The low-fat cheeses are harder than full-fat types because of higher casein

[DOR: 20.1001.1.16807073.2015.17.1.15.6]

Table 1. Coded and actual level of dependent and response variable (texture evaluation). [a]

Treat.	Coded levels			Actual levels			Response			
	X_1	X_2	X_3	XG (gr Kg^{-1}) [b]	WPC (gr Kg^{-1}) [c]	Lct (gr Kg^{-1}) [d]	Hardness (g) [e]	Gumminess (g)	Chewiness (g mm)	Hardness (g) [f]
1	-1	-1	-1	0	0	0	1838	497	3197	71.3
2	1	-1	-1	1	0	0	1102	454	3245	55.7
3	-1	1	-1	0	20	0	663	214	1334	40
4	1	1	-1	1	20	0	933	294	2517	49
5	-1	-1	1	0	0	2	1109	368	2174	65
6	1	-1	1	1	0	2	1993	683	5219	76.7
7	-1	1	1	0	20	2	1029	314	2199	56.3
8	1	1	1	1	20	2	3404	1160	9188	117.3
9	-1	0	0	0	10	1	1163	434	2886	49.3
10	1	0	0	1	10	1	1825	585	4430	77.6
11	0	-1	0	0.5	0	1	1563	487	3583	83.3
12	0	1	0	0.5	20	1	1468	602	4502	67.3
13	0	0	-1	0.5	10	0	830	321	2341	51.3
14	0	0	1	0.5	10	2	1870	621	4801	64.6
15	0	0	0	0.5	10	1	1259	445	3286	62
16	0	0	0	0.5	10	1	1375	530	3208	71
17	0	0	0	0.5	10	1	1353	425	3170	63
18	0	0	0	0.5	10	1	1213	461	3414	71
19	0	0	0	0.5	10	1	1174	423	3154	67
20	0	0	0	0.5	10	1	1572	575	4138	60

[a] X_1, X_2 and X_3, coded level of XG, WPC and Lct respectively; [b] A mixture of xanthan and guar; [c] Whey Protein Concentrate, [d] Lecithin; [e] Measured by TPA test, [f] Measured by penetration test.

Table 2. Regression model coefficient and ANOVA of response variables (texture evaluation).[a]

Source	Hardness (g)[b]		Gumminess (g)		Chewiness (g mm)		Hardness (g)[c]	
	Coefficients	SS	Coefficients	SS	Coefficients	SS	Coefficients	SS
Model	1810.3***	$6.234*10^6$	544.2***	$6.748*10^5$	3550.7***	$4.726*10^7$	75.32***	4290.2
XG[d]	-864.6***	$1.193*10^6$	-174.2***	$1.821*10^5$	-909***	$1.641*10^7$	-19.4***	892.5
WPC[e]	-65.7^{ns}	$1157.78*10^6$	-18.05^{ns}	893.97	-122.6^{ns}	$5.39*10^5$	-2.02^{ns}	48.84
Lct[f]	-396.1***	$1.631*10^6$	-111.85***	$1.871*10^5$	-828.98***	$1.198*10^7$	-7.38***	1269.4
XG×WPC	62.4***	$7.788*10^5$	16.33**	53368.08	126.99**	$3.226*10^6$	1.85**	682.65
XG×Lct	931.5***	$1.7735*10^6$	280.72***	$1.576*10^5$	2200.83***	$9.687*10^6$	19.82**	786.06
WPC×Lct	33.4***	$8.938*10^5$	10.82***	93746.7	82.31***	$5.42*10^6$	0.87**	610.75
Residual	-	$3.227*10^5$	-	63647.7	-	$3.177*10^6$	-	696.08
Lack of fit	-	$2.187*10^{5\ ns}$	-	44359.32^{ns}	-	$2.47*10^{6\ ns}$	-	584.75^{ns}
Pure error	-	$1.040*10^5$	-	19288.3	-	$7.072*10^5$	-	111.33
Cor total	-	$6.556*10^6$	-	$7.384*10^5$	-	$5.044*10^7$	-	4986.3
R^2	-	0.95	-	0.91	-	0.94	-	0.86

[a] *: Significant at $P< 0.05$; **: Significant at $P< 0.01$; ***: Significant at $P< 0.001$; ns: Not significant; [b] Measured by TPA test, [c] Measured by penetration test; [d] A mixture of xanthan and guar; [e] Whey Protein Concentrate, [f] Lecithin.

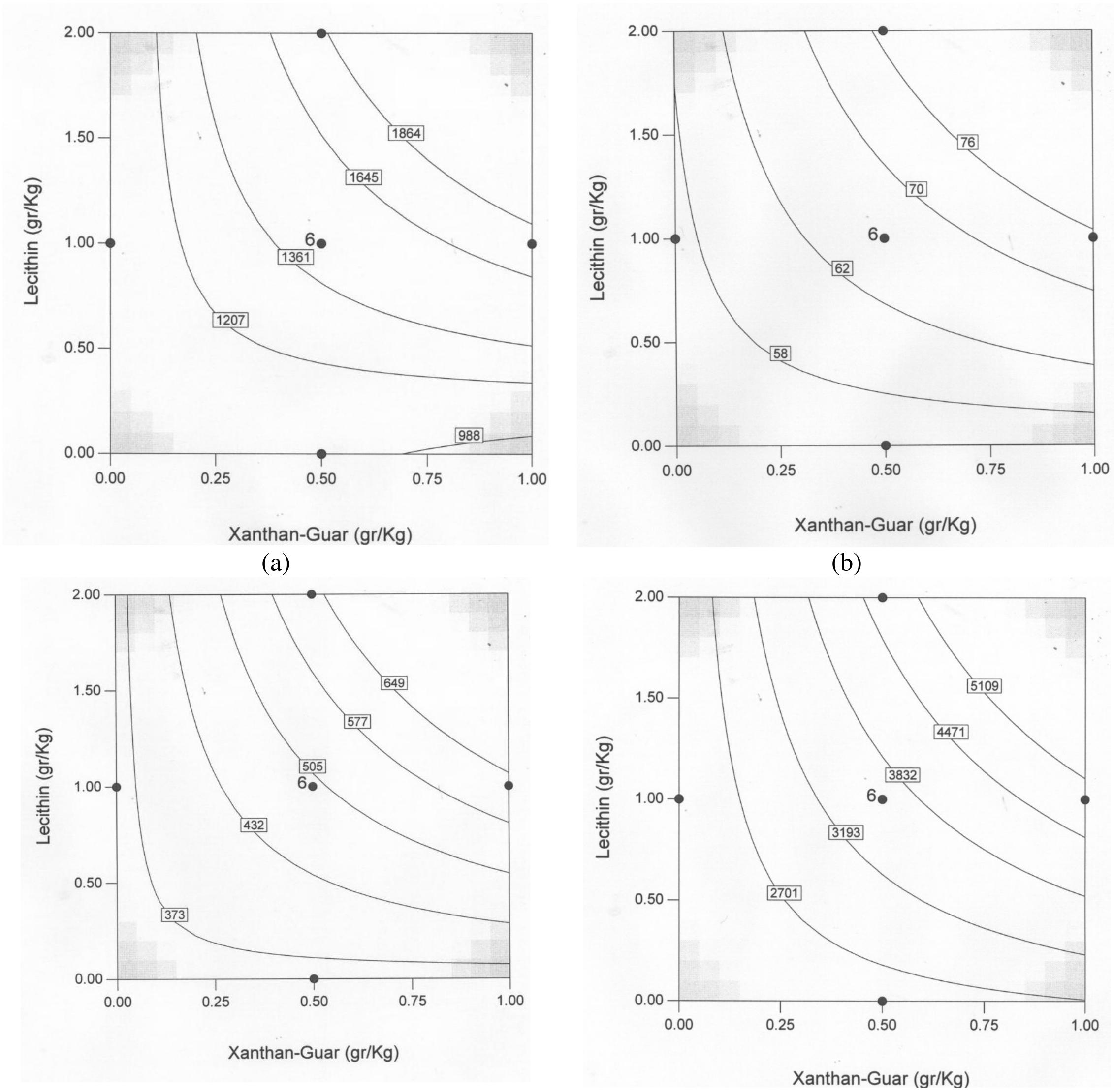

Figure 1. The effects of xanthan-guar and lecithin on (a) hardness Texture profile analysis (TPA) of cheeses, (b) (penetration test) of cheeses, (c) gumminess of cheeses, (d) chewiness of cheeses.

content. The fat in cheese is a lubricant and can break up the protein matrix so that cheese becomes softer (Koca and Metin, 2004). In low-fat cheeses, fewer fat globules are incorporated within the protein matrix and the globules are usually smaller than in full-fat cheeses (Sipahioglu *et al*, 1999). Lobato-Calleros *et al*. (2000) applied WPC in low-fat Manchego cheese and indicated that the hardness of cheese had decreased.

Hardness in cheese sample produced based on central point formula was less than low-fat control cheese, but there were formulas that yielded cheese samples with increased hardness. For example, addition of 1 g kg^{-1} XG, 20 g kg^{-1} WPC and 2 g kg^{-1} Lct produced the hardest cheese. The results indicated that the amount of Lct and XG had an increasing linear effect on hardness of cheese (Figure 1-a). Indeed, different relative quantities of fat replacers were able to increase or decrease the hardness of cheese due to positive interaction between them (Table 2).

Gumminess

Gumminess is defined as the energy needed to disintegrate a semisolid food until it becomes ready for swallowing (Nateghi *et al*., 2012). Gumminess decreased when WPC was added to the low-fat cheese (Table 1). Moreover, gumminess decreased when 1 g kg^{-1} XG or 2 g kg^{-1} Lct was added to retentate. Romieh *et al*. (2002) in the same way reported that adding Simpless-D100 (Microparticulated whey proteins) reduced gumminess of cheese. WPC increased moisture of low-fat cheeses and disrupted protein matrix of cheese so that less force was needed to disrupt the texture of cheese in compression stage. The cheese sample containing maximum amounts of each fat replacer showed the most gumminess (Table 1). This result indicates that there are mixtures of fat replacers which are able to increase the gumminess of low-fat cheese as a result of interactions between fat replacers (Table 2). According to (Figure 1-c), Lecithin and XG had an increasing effect on the gumminess of cheese samples.

Chewiness

Chewiness is defined as the number of masticates required for a certain amount of sample in order to satisfactorily decrease the consistency for swallowing (Nateghi *et al*., 2012). The minimum chewiness was observed when WPC was the only fat replacer used. The WPC decreased chewiness of low-fat cheese, and this finding showed that this level of the WPC was able to loosen the structure of the protein matrix of cheese. Therefore, less energy is needed for chewing of the cheese in the mouth and preparing it for being swallowed. In agreement with this finding, low-fat Kashar cheese containing simpless-D100 as a fat replacer had a lower chewiness than low-fat Kashar cheese without any fat replacer (Koca and Metin, 2004). Similarly, Lobata-Calleros *et al*. (2007) indicated that the chewiness of cheese was decreased by adding WPC to cheese milk. The amount of XG and Lct had an increasing linear effect on the chewiness (Figure 1-d). The low-fat cheese containing 2 g kg^{-1} Lct, 1 g kg^{-1} XG, and 20 g kg^{-1} WPC showed the highest chewiness among all samples. Therefore, fat replacers were able to increase or reduce chewiness based on their proportion because of the significant interactions (Table 2).

Sensory Properties

The mean values, regression model coefficient, and ANOVA of response variables of sensory evaluation were determined (Table 3 and 4). Also, the effect of fat replacers on sensory characteristics are shown in (Figures 2a-d).

Texture

The effects of XG and lecithin on the texture of low-fat cheese were significant (Table 4). The texture score of cheese was positively impressed by the use of XG and lecithin (Figure 2-a). WPC did not have any significant effect on the texture of cheese (Table 4). Different proportions of fat replacers yielded low-fat cheeses with different texture scores. Low-fat cheese without any fat replacer had a lower texture score because it was very hard and rubbery. This was expected because of the important role of fat in the body and texture of cheeses. A Low-fat cheese is generally recognized to have hard and rubbery texture (Mistry, 2001). Fat replacers disrupt the continuous protein matrix of low-fat cheeses resulting in improvement in texture. Similarly, Sipahiuglu *et al*. (1999) reported increased texture score when lecithin was used in low-fat Feta cheese.

Taste

In our study, low-fat cheese without any fat replacers had the minimum taste score

[DOR: 20.1001.1.16807073.2015.17.1.15.6]

Table 3. Coded and actual level of dependent and response variables (sensory evaluation).[a]

Treat.	Coded levels			Actual levels			Response			
	X_1	X_2	X_3	XG (gr Kg^{-1})[b]	WPC (gr Kg^{-1})[c]	Lct (gr Kg^{-1})[d]	Texture	Taste	Appearance	Acceptance
1	-1	-1	-1	0	0	0	1.8	1.3	1.8	1.3
2	1	-1	-1	1	0	0	2.7	3.5	4	3.7
3	-1	1	-1	0	20	0	3.2	4	4.1	3.7
4	1	1	-1	1	20	0	2.9	4.2	4.1	4.2
5	-1	-1	1	0	0	2	3	2.4	1.2	2.2
6	1	-1	1	1	0	2	4.9	2.5	3.1	3.2
7	-1	1	1	0	20	2	3.3	2.4	2	2.2
8	1	1	1	1	20	2	3.8	1.9	1.3	1.9
9	-1	0	0	0	10	1	2.4	3	1.7	2.5
10	1	0	0	1	10	1	3.5	2.9	3.1	3.2
11	0	-1	0	0.5	0	1	2.7	2.4	2.1	2.2
12	0	1	0	0.5	20	1	3.3	3.1	2.6	2.2
13	0	0	-1	0.5	10	0	2.4	3.2	3.6	3.2
14	0	0	1	0.5	10	2	3.7	2.6	2.1	2.7
15	0	0	0	0.5	10	1	3.5	2.9	2.6	3
16	0	0	0	0.5	10	1	3.5	3.2	3	2.1
17	0	0	0	0.5	10	1	3	3.2	2.9	3.2
18	0	0	0	0.5	10	1	3.5	3.1	3.7	2.8
19	0	0	0	0.5	10	1	3.7	2.7	3.1	2.2
20	0	0	0	0.5	10	1	3.4	3.3	3.3	2.4

[a] X_1, X_2 and X_3, coded level of XG, WPC and Lct respectively; [b] A mixture of xanthan and guar; [c] Whey Protein Concentrate, [d] Lecithin.

Table 4. Regression model coefficient and ANOVA of response variables (sensory evaluation).[a]

Source	Texture		Taste		Color		Acceptance	
	Coefficients	SS	Coefficients	SS	Coefficients	SS	Coefficients	SS
Model	1.74***	7.09	1.69***	7.29	1.78***	13.03	1.31***	7.72
XG[b]	1.06***	1.66	1.69[ns]	0.32	2.39**	2.29	2.22**	1.78
WPC[c]	0.08[ns]	0.18	0.12**	1.21	0.12[ns]	0.38	0.11[ns]	0.29
Lct[d]	0.62***	3.19	0.39***	2.00	0.24***	6.08	0.43**	1.47
XG×WPC	-0.07**	0.98	0.06**	0.83	0.12**	2.78	0.08**	1.31
XG×Lct	0.45*	0.41	0.69**	0.95	0.25[ns]	0.13	0.56*	0.64
WPC×Lct	0.03**	0.66	0.05***	1.99	0.04*	1.36	0.05**	2.23
Residual	-	0.93	-	1.02	-	2.30	-	1.81
Lack of fit	-	0.65[ns]	-	0.75[ns]	-	1.51[ns]	-	0.85[ns]
Pure error	-	0.28	-	0.27	-	0.79	-	0.97
Cor total	-	8.01	-	8.31	-	15.33	-	9.53
R^2	-	0.88	-	0.88	-	0.85	-	0.81

[a] *: Significant at $P< 0.05$; **, Significant at $P< 0.01$; ***: Significant at $P< 0.001$; ns: Not significant; [b] A mixture of xanthan and guar; [c] Whey Protein Concentrate, [d] Lecithin.

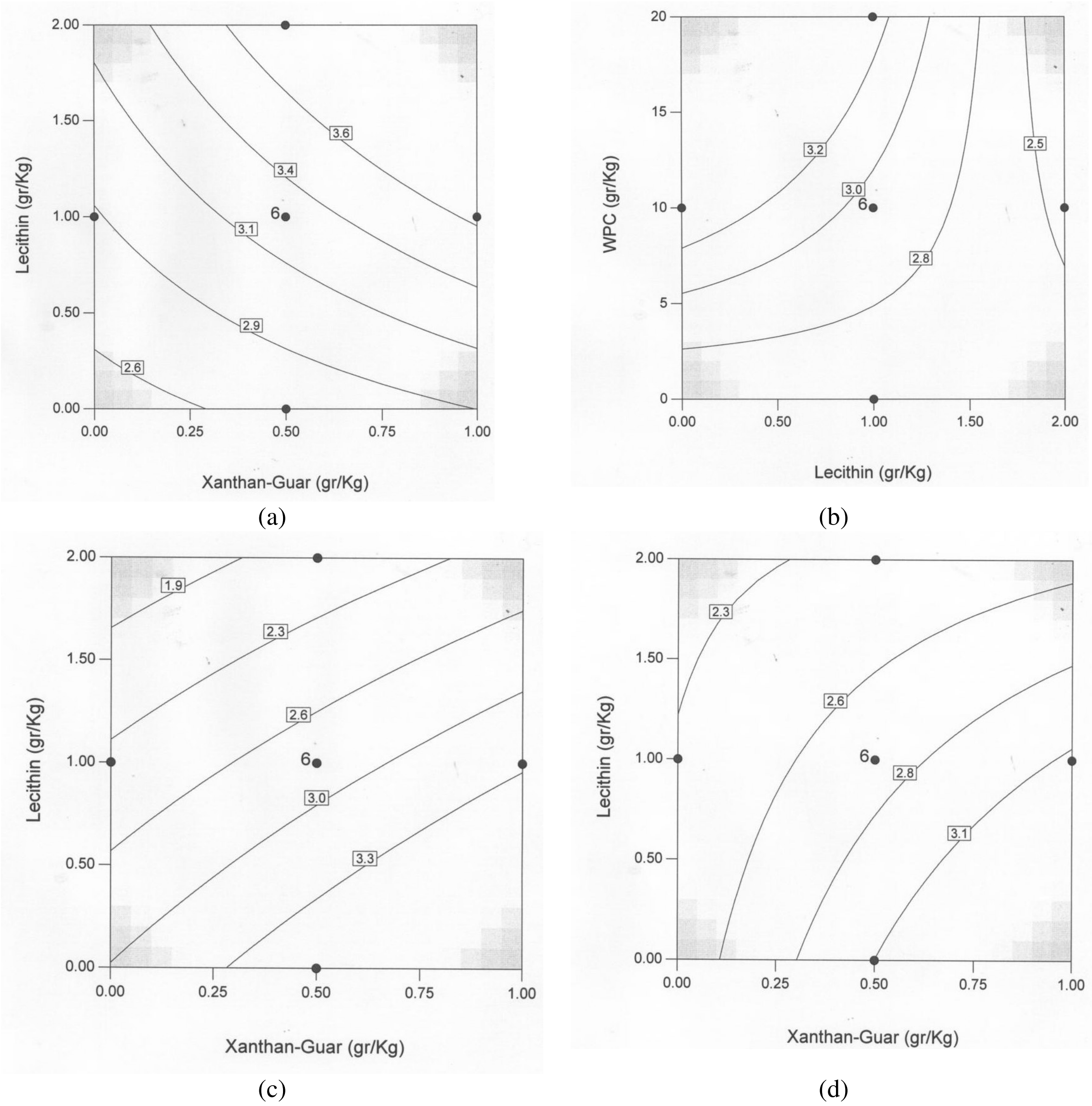

Figure 2. The effects of (a) xanthan-guar and lecithin on texture score of cheeses, (b) WPC80 and lecithin on taste of cheeses, (c) lecithin and xanthan-guar on appearance score of cheeses, (d) xanthan-guar and lecithin on total acceptance score of cheeses.

(Table 3). Milk fat is recognized to be a very important component influencing cheese flavor. Low fat cheeses contain more moisture and less fat resulting in dilution of fat flavor and less pronounced flavor than full-fat cheeses (Sepahioglu *et al*., 1999). Different mixtures of fat replacers improve more or less taste score of low-fat cheese. Lecithin decreased and WPC significantly increased the taste score of low-fat cheeses (Figure 2-b). The effect of xanthan-guar on the taste score was not significant (Table 4). The panelists stated that the cheese samples containing lecithin had unfavorable and non-dairy taste, therefore, the cheese samples without lecithin had a higher taste score. Sepahioglu *et al*. (1999) reported that cheeses with lecithin were criticized for foreign flavors by panelists so that lecithin adversely affected the flavor of low-fat Feta cheese.

Table 5. Properties of optimized low-fat cheese in comparison with full-fat and low-fat cheeses.[a]

Treat.	Texture	Color	Taste	Acceptance	Hardness (g)[b]	Chewiness (g mm)	Gumminess (g)	Hardness (g)[c]
LF[d]	1.9 [b]	1.8[b]	1.4[b]	1.3[b]	1838[a]	3198[a]	497[a]	71.3[a]
OLF[e]	4.0[a]	4.2[a]	3.6[a]	3.4[a]	944[b]	2273[b]	321[b]	51.3[b]
FF[f]	4.3[a]	4.1[a]	4.3[a]	4.0[a]	973[b]	1825[c]	270[b]	56.3[b]
Model	3.1[a]	4.0[a]	4.0[a]	3.6[a]	800[b]	2189[b]	295[b]	46.8[b]

[a] Values are the averages of Triplicates. Different letters in each column are indicative of a significant statistical difference (P< 0.05) between the values; [b] Measured by TPA test, [c] Measured by penetration test. [d] Low-Fat cheese; [e] Optimized Low-Fat cheese, [f] Full-Fat cheese.

Appearance

Feta is known as white cheese and fat reduction causes mainly changes in color and appearance of cheese because lack of the fat gives opacity to cheese. Fat reduction made the mozzarella cheese less white and more translucent (Rudan *et al*., 1999). In our study, in agreement with the aforementioned literatures, low-fat cheese had a lower appearance score because of translucency and reduced whiteness. The mixtures of fat replacers generally improved the appearance of low-fat cheeses (Table 3), but lecithin gave faint yellow color to cheese, which caused the decrease in appearance score (Figure 2-c).

Total Acceptance

According to (Figure 2-d), increasing the lecithin and XG, respectively, decreased and enhanced the total acceptance score of low-fat cheese. Lct had negative effects on flavor and appearance of cheese, as was already discussed.

Numerical Optimization

The optimization procedures were performed to predict the exact optimum level of independent variables (xanthan-guar, WPC80 and lecithin) leading to the desirable response goals (sensory and texture properties of full-fat cheese). The calculation was based on the analysis of sensory and physical evaluation results (Tables 1-4). The optimum mixture was determined as 0.5 g kg^{-1} XG, 0.13 g kg^{-1} Lct, and 19.47 g kg^{-1} WPC with 0.75 overall desirability and characteristics described in Table 5 (denoted in the table as Model). A low-fat cheese sample based on optimized formula was prepared and its sensory and physical properties were measured (Table 5). The results did not show any significant differences between sensory properties of FF and optimized LF cheese. Furthermore, optimized LF cheese showed more gumminess and chewiness, probably because of its higher cohesiveness and springiness. Comparison between LF cheese and optimized LF cheese showed that sensory properties successfully improved. Furthermore, hardness, gumminess, and chewiness of LF cheese were greatly more than the optimum quantity, while applying an optimum mixture of fat replacers was effectively able to improve physical properties of low-fat cheese.

Abbreviation

XG: A mixture of 20% guar and 80% xanthan; Lct**:** Lecithin; WPC: WPC80; FDM: Fat in Dry Matter; LF: Low-Fat; FF: Full-Fat, UF: Ultra-Filtration.

REFERENCES

1. Bhaskaracharya, R. K. and Shah, N. P. 2001. Texture and Microstructure of Skim Milk Mozzarella Cheeses Made Using Fat Replacers. *J. Dairy Technol.*, **56**: 9-14.

2. Drake, M. A., Herrett, W., Boylston T. D. and Swanson, B. G. 1996. Lecithin Improves Texture of Reduced Fat Cheeses. *J. Food Sci.*, **61**: 639-642.
3. Drake, M. A., Chen, X. Q., Gerard P. D. and Gurkin, S. U. 1998. Composition and Quality Attributes of Reduced-Fat as Affected by Lecithin Type. *J. Food Sci.*, **63**: 6.
4. Drake, M. A., Truong V. D. and Daubert, C. R. 1999. Rheological and Sensory Properties of Reduced–fat Processed Cheeses Containing Lecithin. *J. Food Sci.*, **64**: 4.
5. El-Neshawy, A. A., Abdel Baky, A. A., Rabie, A. M. and Ashour M. M. 1986. An Attempt to Produce Low Fat Cephalotyre (Ras) Cheese of Acceptable Quality. *Food Chem.,* **22**: 123-137.
6. Erdem, Y. K. 2005. Effect of Ultra-filtration, Fat Reduction and Salting on Textural Properties of White Brined Cheese. *J. Food Eng.*, **71**: 366-372.
7. Fenelon, M. A. and Guinee, T. P. 1999. The Effect of Milk Fat on Cheddar Cheese Yield and Its Prediction, Using Modifications of the Van Slyke Cheese Yield Formula. *J. Dairy Sci.*, **82**:11, 87-99.
8. Fox, P. F., Guinee, T. P., Cogan, T. M. and McSweeny, P. L. H. 2000. *Fundamental of Cheese Science*. Aspen. USA. 638 PP.
9. Ghods Rohani, M., Mortazavi, S. A., Mazaheri Tehrani, M. and Razavi, S. M. A. 2008. Effect of Processing Conditions on Chemical and Sensory Properties of Ultra-filtrated Feta Cheese Made from Cow's Milk and Soymilk Blend. *J. Food Sci. Technol.*, **6(1):** 85-96.
10. Ghods Rohani, M., Mortazavi, S. A., Mazaheri Tehrani, M. and Razavi, S. M. A. 2009. Effect of Processing Conditions on Physical, Chemical and Sensory Properties of Ultra-Filtrated Feta Cheese Made from Cow's Milk and Soymilk Blend. PhD. Thesis, Ferdowsi University of Mashad, Iran.
11. Gunasekaran, S. and Mehmet, A. k. M. 2003. *Cheese Rheology and Texture*. 1st Edition, CRC Press, 512 PP.
12. Haumann, B. F. 1986. Getting the Fat Out: Researchers Seek Substitutes for Full-fat Fat. *J. Am. Oil Chemists Soc.*, **63**: 278-288.
13. Institute of Standards and Industrial Research of Iran (ISIRI). 2002. *Fresh Cheese, Specification and Test Methods: No. 6629*. The Institute of Standards and Industrial Research of Iran, Tehran.
14. Katsiari, M. C., Voutsinas, L. P. and Kondyli, E. 2002. Improvement of Sensory Quality of Low-fat Kefalograviera Type Cheese with Commercial Adjunct Cultures. *Inter. Dairy J.*, **12**: 757-764.
15. Kavas, G., Oysun, G., Kinik, O. and Uysal, H. 2004. Effect of Some Fat Replacers on Chemical, Physical and Sensory Attributes of Low-fat White Pickled Cheese. *Food Chem.*, **88**: 381-388.
16. Koca, N. and Metin, M. 2004. Textural, Melting and Sensory Properties of Low-fat Fresh Kashar Cheese Produced by Using Fat Replacers. *Inter. Dairy J.*, **14**: 365-373.
17. Konuklar, G., Inglett, G. E., Warner, K. and Carriere, C. J. 2004. Use of *ß*-glucan Hydrocolloidal Suspension in the Manufacture of Low-fat Cheddar Cheeses: Textural Properties by Instrumental Methods and Sensory Panels. *Food Hydrocol.*, **18**: 535-545.
18. Laloy, E., Vuillemard, J. C., El Soda, M. and Simard, R. E. 1996. Influence of Fat Content of Cheddar Cheese on Retention and Localization of Starters. *Inter. Dairy J.*, **6**: 729-740.
19. Lobato-Calleros, C., Reyes-Hernandez, J., Beristain, C. I., Hornelas-Uribe, Y., Sanchez-Garcia, J. E. and Vernon-Carter, E. J. 2007. Microstructure and Texture of White Fresh Cheese Made with Canola Oil and Whey Protein Concentrate in Partial or Total Replacement of Milk. *Food Res. Inter.*, **40**: 529-537.
20. Lteif, L., Olabi, A., Baghdadi, O. K. and Toufeili, I. 2009. The Characterization of the Physicochemical and Sensory Properties of Full-fat, Reduced-fat and Low-fat Ovine and Bovine Halloumi. *J. Dairy Sci.*, **92**: 4135-4145.
21. Lucca, P. A. and Tepper, B. J. 1994. Fat Replacers and the Functionality of Fat in Foods. *Trends Food Sci. Technol.*, **5**: 12-19.
22. Mistry, V. 2001. Low-fat Cheese Technology. *Inter. Dairy J.*, **11**: 413-422.
23. Nateghi, L., Roohinejad, S., Totosaus, A., Mirhosseini, H., Shuhaimi, M., Meimandipour, A., Omidizadeh, A. and Abd-Manap, M. Y. 2012. Optimization of Textural Properties and Formulation of Reduced Fat Cheddar Cheeses Containing Fat Replacers. *J. Food, Agr. Envir.* **10(2):** 46-54.

24. Rashidi, H., Mazaheri Tehrani, M., Razavi, S. M. A. and Ghods-Rohani, M. 2011. The Effect of Fat-reduction and $CaCl_2$ Levels on Sensory and Textural Characteristics of UF-Feta Cheese Made from Retentate Powder of Milk Ultra-filtration. *Iranian Food Sci. Technol. Res. J.*, 7(3): 218-226.
25. Rashidi, H., Mazaheri Tehrani, M., Razavi, S. M. A. and Ghods-Rohani, M. 2012. Determination of Coagulation and Chemical Characteristics of UF-Feta Cheeses Made from Retentate Powder in Different Levels of Fat and $CaCl_2$. *J. Food Sci. Technol.*, **9(35):** 25-34.
26. Romieh, E., A., Michaelidou, A., Biliaderis, C. G. and Zerfiridis, G. K. 2002. Low-fat White-Brined Cheese Made from Bovine Milk and Two Commercial Fat Mimetics: Chemical, Physical and Sensory Attributes. *Inter. Dairy J.*, **12**: 525-540.
27. Rudan, M. A., Barbano, D. M., Yun J. J. and Kindstedt, P. S. 1999. Effect of Fat Reduction on Chemical Composition, Proteolysis, Functionality and Yield of Mozzarella Cheese. *J. Dairy Sci.*, **82**: 661-672.
28. Saint-Eve, A., Lauverjat, C., Magnan, C., Deleris, I. and Souchon, I. 2009. Reducing Salt and Fat Content: Impact of Composition, Texture and Cognitive Interaction on the Perception of Flavored Model Cheeses. *Food Chem.*, **116**: 167-175.
29. Sipahioglu, O., Alvarez, V. B., and Solano Lopez C. 1999. Structure, Physicochemical and Sensory Properties of Feta Cheese Made with Tapioca Starch and Lecithin as Fat Mimetic. *Inter. Dairy J.*, **9**: 783-789.
30. Tamime, A. Y., Muir, D. D., Shenana, M. E., Kalab, M., and Dawood, A. H. 1999. Processed Cheese Analogues Incorporation Fat Substitutes. 2. Rheology, Sensory Perception of Texture and Microstructure. *Lebensmittel-wissenschaft undd-Technologie-Food Sci. Technol.*, **32**: 50-59.
31. Totosaus, A. and Guemes-Vera N. 2008, Effect of *α* and *κ*-Carrageenans as Fat-replacers in Low-fat Oaxaca Cheese. *Inter. J. Food Prop.,* **11**: 656-668.
32. Volikakis, P., Biliaderis, C. G., Vamvakas, C. and Zerfiridis, G. K. 2004. Effects of a Commercial Oat-ß-Glucan Concentrate on the Chemical, Physicochemical and Sensory Attributes of a Low-fat White Brined Cheese Product. *Food Res. Inter.*, **37**: 83-94.
33. Zisu, B. and Shah, N. P. 2005. Textural and Functional Changes in Low-fat Mozzarella Cheese in Relation to Proteolysis and Microstructure as Influenced by the Use of Fat Replacers, Pre-acidification and EPS Starter. *Inter. Dairy J.*, **15**: 957-972.

بهبود ویژگی های بافتی و حسی پنیر فتای فراپالایش کم چرب ساخته شده با جایگزین های چربی

ح. رشیدی، م. مظاهری تهرانی، س. م. ع. رضوی و م. قدس روحانی

چکیده

مصرف چربی های اشباع باعث افزایش خطر ابتلا به بیماری عروق کرونر و سرطان می شود. به همین جهت کاهش چربی در پنیر فتای فراپالایش (دارای حدود ۴۵ درصد چربی در ماده خشک) نیز مطلوب است، اما متاسفانه دارای اثرات منفی بر بافت و ویژگی های حسی پنیر می باشد. در این تحقیق با استفاده از روش سطح پاسخ، اثرات افزودنWPC80 (۰–۲۰ گرم بر کیلوگرم)، لسیتین (۰–۲ گرم بر کیلوگرم) و مخلوطی از زانتان و گوار (۰–۱ گرم بر کیلوگرم) بر روی ویژگی های حسی و بافت مکانیکی پنیر فتای کم چرب حاصل از ریتنتیت با ۶ درصد چربی مورد بررسی قرار گرفت. سفتی، حالت آدامسی و حالت صمغی

[DOR: 20.1001.1.16807073.2015.17.1.15.6]

پنیر با افزودن لسیتین، زانتان و گوار بهبود یافت اما افزودن WPC80 بر این ویژگی ها اثر منفی داشت. علاوه بر این، نتایج نشانگر اثر منفی لسیتین بر طعم و مزه، پذیرش و ظاهر، اثرات مثبت لسیتین بر بافت حسی، اثرات مثبت استفاده از WPC80 در طعم و مزه و اثرات مثبت زانتان، گوار بر بافت حسی و پذیرش بود. در نهایت، روش بهینه سازی پاسخ ترکیبی برای تعیین فرمول بهینه پنیر کم چرب (۱۹/۴۷ گرم بر کیلوگرم WPC80، ۰/۵ گرم بر کیلوگرم زانتان، گوار و ۰/۱۳ گرم بر کیلوگرم لسیتین) مورد استفاده قرار گرفت. ارزیابی نمونه آزمایشی تولید شده بر اساس فرمول بهینه نشان داد که خواص حسی و مکانیکی بافت آن، مشابه ویژگی های تخمین زده شده توسط بهینه سازی و نمونه پنیر پر چرب است.

[DOR: 20.1001.1.16807073.2015.17.1.15.6]