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The Feasibility of Manufacturing Low Fat Pizza Cheese by Use of Pre-Gelatinized Corn Starch

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ABSTRACT: In this study pre-gelatinized corn starch was used in order to improve the sensory and physicochemical properties of low fat pizza cheese. Therefore, the effect of three independent variables including low fat milk powder (45-100%), fat (0-45%) and pregelatinized corn starch (0-10%) on physicochemical properties of low fat pizza cheese was evaluated using mixture statistical design by design expert software. Fifteen treatments were tested and according to the results the used statistical design was successfully applied for evaluation and optimization of the formulation of low fat pizza cheese. All physicochemical properties were significantly affected by the mixture components. As the results showed 67.56% low fat milk powder, 27.93% fat and 4.5% starch were the optimal quantities in the formulation. Melt ability, acidity, elasticity, firmness, total soil matters, flavor, texture and total acceptance were measured and indicated at highest acceptability among the treatments, 4.08, 0.46, 13.91, 14.11, 49.68, 3.85, 4.26 and 3.78 respectively. The closeness of estimated and measured values of responses for optimized formulation suggested the fitness of the selected models and their high predictability.

Keywords: Low-Fat, Pizza Cheese, Pre-Gelatinized Corn Starch.

Introduction

Obesity has been growing in European countries in recent years due to consumption of fatty foods and lack of consuming foods rich in dietary fiber (Todd *et al.*, 2015). On the other hand, the research has shown a direct significant relationship between increased dairy-derived fat consumption and the rate of mortality caused by cardiovascular diseases (Huth and Park, 2012). Mozzarella or pizza cheese is a kind of soft unripen cheese which is classified as a member of pasta-filata family and has originated from Italy. Because of high fat content in pizza cheese (> 45% dry matter), the consumers are concerned about the fat contained in this cheese and other dairy products and directing the attention towards manufacturing low fat dairy products including low and non fat pizza cheese (McMahon *et al.*, 1996). Given this fact as well as increased costs of production and storage, food industry has taken steps towards solving this problem and manufacturing healthier foods through producing low fat foods and fat substitution with dietary fiber (Mistry,

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2001; Mounsey and O'Riordan, 2008[a]). Today the researchers are seeking fat replacers application in order to improve the formulation of pizza cheese. The results revealed that use of dietary fiber and starch could affect macroscopic properties of product including flow, stability, textural and mouth feel characteristics. Also starch depending on the used source (ratio of amylase and amylopectin) and type of starch (pre – gelatinized, cross – linked, etc) might have different effect on such properties (Mounsey and O'Riordan, 2008[a]). Other research investigates the stretch ability and melts ability of pizza cheese (Rehman *et al.*, 2003; Jana and Mandal, 2011). Optimal properties of mozzarella cheese are mainly due to the activity of lactic acid on para-caseinate dicalcium, most of which is converted to para-caseinate mono-calcium at pH of 5.2-5.4, which is a filamentous cheese. It gives and shines (Dai *et al.* 2018). This cheese is one of the types of cheese that has grown the most in terms of production in the last century. The popularity of pizza, one of the most important components of which is pizza cheese, among people, especially children, is the reason and there has been an increase in production (Fu and Nakamura, 2018). Therefore, it seems necessary to produce a pizza cheese with desirable properties to compete with other products. Pre-gelatinized starch is substantially modified starch that has undergone an individual cooking process (complete gelatinization and immediate or subsequent drying). Pre-gelatinized starch can melt simply in cold water. Besides, no heat treatment is needed to manufacture the paste form, making it a suitable technique for heat-sensitive foods (Alcázar-Alay and Meireles, 2015). The main goal of this study was to produce a low or reduced fat pizza cheese with melt ability and physicochemical properties similar to those of high fat counterpart therefore it would be used by those people with difficulty to consume fatty foods.

Materials and Methods

- *Materials*

Skim milk powder and cream was provided by Pegah Company, pre gelatinized starch was provided by Ghazvin glucose company (Tehran, Iran). Starter and rennet was purchased from Micro milk, Italian company. Salt has been purchased from Golha, Iran. All the chemicals were provided from Merck Company, Germany.

- *Methods*

- *Production of mozzarella cheese*

Different range of pre gelatinized starch percentage (0-45%), cream 30% fat (0-10%) and skim milk powder (45-100%) as independent factors were mixed according to mixture design in design expert version 7. The experimental design is shown in Table 1. The mixture of each treatment was mixed with 900 ml of distilled water and a mixture 10 %w/v was prepared. The mixture was then homogenized with homogenizer (model H.G-15D, Germany), at 7000 PSI for 5 minutes. It was then pasteurized at 95 ° C for 10 minutes. The milk samples were inoculated with starters of *streptococcus thermophilus* and lactobacillus delbrueckii subsp. *bulgaricus* and kept at 37 °C for 45 minutes. Then 0.02 % rennet was added to the milk samples and allowed the mixture set and the cured formed for 20 minutes.

The curds cut into 1 to 2 cm cubes with stainless steel knives to remove whey and then 2% wt/wt salt was added to the curds and whey. The cooking operation was performed with gentle stirring for 30 minutes to reduce the pH to about 5.5. The Whey is removed from the curds. Then in

Table 1. formulation of treatments

Formulation	Starch (%)	Fat (%)	Skim milk powder (%)
1	0.00	0.00	100
2	5.00	45.00	50.00
3	2.50	33.75	63.75
4	10.00	45.00	45.00
5	7.50	33.75	58.75
6	10.00	45.00	45.00
7	0.00	0.00	100.00
8	0.00	45.00	55.00
9	3.33	15.00	81.66
10	5.00	0.00	95.00
11	0.00	45.00	55.00
12	10.00	0.00	90.00
13	10.00	0.00	90.00
14	2.50	22.50	75.00
15	10.00	22.50	67.50

order to stretch curds were placed in a laboratory cooker and stirred at 80 °C for 30 minutes at 14 rpm. The cheeses were taken out of the mixer and put into stainless steel molds and transferred to the refrigerator. After forming of the cheeses were taken out of the mold and packed in polyethylene containers (Mazaheri Nasab et al., 2012).

- *Physical and chemicals properties of mozzarella cheese*

In order to determine pH, solid matter, acidity, protein and fat, contents the Iranian National Standard No. 4658 was applied (ISIRI., 2002). Cheese firmness was measured by four to six cylindrical samples (29-mm diameter) of each cheese and were arranged using a cork borer and cut to the desired length (29 mm). The samples were engaged in an airtight plastic bag and held at 8 ^{o}C overnight. Each sample was taken from storage and compressed immediately to 30% of the original height at a rate of 50 mm/min between a 140 mm cross-head and base-plate on a Model 4301 Universal Instron Testing Machine (Instron Ltd, High Wycombe HP12 35Y, UK). The firmness was the force required to compress the cheese to 30% of the original height (Guinee *et al.,* 2001). Melting time was determined as the time required for the constant weight of shredded cheese (1.73 kg/m^2) to melt and thaw in a melt mass without crushed identity, at heating to 280 °C. Flow capability was defined as the percentage of increase in the diameter of the cheese disk in melting at 280 °C for 4 minutes. The ability to stretch the melted cheese on a cooked pizza pie with a uniaxial extension was measured at a speed of 0.066 m/s. Before heating, the shredded cheese was evenly distributed in a constant load (2.5 kg/m^2) on a pizza base that had already been cut in half (Guinee *et al*. 2001).

- *Sensory properties measurement*

Sensory evaluation carried out by 6 trained panelists using 5- point hedonic test for appearance, flavor, taste, texture, and total acceptance (Guinee *et al.*, 2001).

- *Statistical analysis*

According to mixture design 15 treatments were designed and analyzed by design expert version 7. The experimental design is shown in Table 1. The results were reported as mean ± SD were analyzed by one-way ANOVA (Duncan) at a 95% confidence level using Minitab 16 software.

Results and Discussion

Table 2 shows the physicochemical properties of the low fat pizza cheese with different formulations. In general, the response for each property showed significant difference ($p<0.05$). Sensory properties of the produced low fat pizza cheese are given in Table 3. Figures 1-9 depict the effect of independent variables on each response. The reddish and bluish parts respectively exhibit the greatest and the lowest response rate. The variations of response rate are expressed with increase or decrease in each component, namely by direct movement along the top of each component through the opposite side.

- *Physicochemical properties of low fat pizza cheese*

pH is amount of the most important factors affecting the final properties of the product. Final pH is commonly affected by the activity of residual rennet as well as the enzymes produced by microbial activity of starters (Fox *et al.*, 2004). Most of formulations showed no significant difference in pH from the control sample and the reason for the difference may be the experimental error ($p\geq0.05$). According to the results presented in Table 2 pH values for all formulations were mostly in the standard range. Figure 1 shows the interactive effect of independent variables on pH value of low fat pizza cheese. As shown in the Table 2 the highest and the lowest pH values were found for T9 and T5, respectively. pH value of T5 was significantly different from that of control sample, however it was not significant for T9 which had the highest pH. Optimal properties of mozzarella cheese are mainly due to the activity of lactic acid on para-caseinate dicalcium, most of which is converted to para-caseinate mono-calcium at pH = 5.2-5.4, which is a filamentous cheese. It gives and shines (Jana and Mandal, 2011). This can be attributed to the nature of low-fat milk powder and its pH (low-fat milk powder is in the neutral range). On the other hand, the pH of this cheese decreased with increasing the amount of starch in the formulation, which could be related to the increase in the acidity of the cheese in these conditions. The process of making process pizza cheese is a mixing process with heating. Therefore, at the same time as mixing, the moisture drop occurs due to evaporation. As the amount of trisodium citrate increased, the moisture content of the mixture decreased. Hajimohammadi Farimani *et al*., (2011) reported that as the ratio of white cheese in the formulation increased pH value dropped. Wadhwani *et al.*, (2011) investigated improvement in melting and baking properties of low-fat Mozzarella cheese and showed that the pH of the cheeses was measured by the amount of vinegar added before renneting (to acidify milk to pH 5.90). In another study, Metzger *et al*., 2001 showed that during refrigeration, the chemical properties of low-fat mozzarella cheese were further affected by milk preacidification to pH 5.8 with citric acid.

Shabani *et al*.2012 showed that with the addition of white cheese as a substitute in processed pizza cheese experienced a significant decrease in pH. The reason was the lower pH of white cheese than processed pizza cheese. The most suitable pH for processed cheese is 5.1-6.6, because this pH helps in protein formation and hydration, emulsifier solubility and Calcium ion confinement.

Table 2. Physicochemical properties of low fat pizza cheese

Formulation	pH	Solid matter (%)	Acidity % lactic acid	Protein (%)	Fat (%)	Stretch ability	Firmness	Melt ability (cm)
1	5.39 ± 0.005^{a}	49.00 ± 1.0^{d}	0.18 ± 0.05^{d}	21.08 ± 0.05^{a}	0.60 ± 0.3^{i}	14.1 ± 5.0^{c}	9.2 ± 5.0^{fg}	3.5 ± 0.25^{c}
2	5.36 ± 0.005^{b}	55.62 ± 0.5^{b}	0.90 ± 0.05^{a}	20.88 ± 0.08^{a}	26.6 ± 0.5^{a}	7.0 ± 5.5^{f}	13.1 ± 0.5^{f}	7.0 ± 0.15^{a}
3	5.37 ± 0.005^{ab}	41.81 ± 1.5^{f}	0.45 ± 0.03^{b}	21.00 ± 0.05^{a}	4.6 ± 1.0^{g}	12.0 ± 5.5^{d}	10.2 ± 5.0^{fg}	1.0 ± 0.25^{e}
4	5.36 ± 0.005^{b}	57.23 ± 0.5^{b}	0.90 ± 0.03^{a}	18.64 ± 0.05^{d}	18.6 ± 1.0^{d}	2.0 ± 5.5^{h}	19.1 ± 5.0^{c}	6.7 ± 0.20^{ab}
5	5.35 ± 0.005^{b}	59.57 ± 2.0^{ab}	0.45 ± 0.03^{b}	19.10 ± 0.05^{c}	4.6 ± 0.5^{g}	10.0 ± 5.0^{e}	14.0 ± 5.5^{e}	7.0 ± 0.20^{a}
6	5.39 ± 0.01^{a}	57.30 ± 0.5^{b}	0.90 ± 0.05^{a}	18.64 ± 0.05^{d}	25.0 ± 0.5^{b}	2.0 ± 0.5^{h}	19.1 ± 0.0^{c}	6.5 ± 0.05^{b}
7	5.39 ± 0.01^{a}	48.70 ± 0.5^{d}	0.36 ± 0.04^{c}	21.08 ± 0.05^{a}	0.60 ± 0.3^{i}	14.1 ± 5.0^{c}	10.2 ± 5.0^{fg}	3.5 ± 0.20^{c}
8	5.39 ± 0.005^{a}	46.00 ± 0.5^{e}	0.36 ± 0.02^{c}	18.80 ± 0.05^{d}	25.0 ± 0.5^{b}	4.0 ± 0.5^{g}	8.0 ± 5.5^{g}	3.0 ± 0.20^{cd}
9	5.40 ± 0.01^{a}	46.80 ± 1.5^{e}	0.90 ± 0.03^{a}	46.80 ± 1.5^{e}	0.90 ± 0.03^{a}	21.0 ± 0.5^{a}	15.0 ± 0.5^{e}	2.5 ± 0.10^{d}
10	5.37 ± 0.005^{ab}	49.21 ± 0.5^{d}	0.45 ± 0.03^{b}	20.99 ± 0.08^{a}	16.6 ± 0.5^{e}	2 ± 17.0^{bc}	17.0 ± 5.5^{d}	0.00 ± 0.00^{f}
11	5.39 ± 0.01^{a}	45.34 ± 1.5^{e}	0.36 ± 0.02^{c}	19.12 ± 0.05^{c}	21.6 ± 1.0^{c}	4.0 ± 0.5^{g}	8.1 ± 0.0^{g}	3.0 ± 0.25^{cd}
12	5.39 ± 0.01^{a}	52.94 ± 1.0^{c}	0.45 ± 0.05^{b}	21.02 ± 0.08^{a}	2.6 ± 0.5^{h}	13.0 ± 0.5^{d}	25.1 ± 5.0^{a}	0.00 ± 0.00^{f}
13	5.36 ± 0.005^{b}	52.86 ± 0.5^{c}	0.45 ± 0.03^{b}	21.02 ± 0.05^{a}	2.2 ± 0.5^{h}	13.0 ± 5.5^{d}	26.1 ± 0.0^{a}	0.00 ± 0.00^{f}
14	5.39 ± 0.005^{a}	62.50 ± 1.0^{a}	0.45 ± 0.05^{b}	20.45 ± 0.08^{ab}	21.06 ± 1.0^{c}	18.1 ± 5.0^{b}	12.1 ± 5.5^{f}	6.50 ± 0.00^{d}
15	5.38 ± 0.005^{a}	51.23 ± 1.0^{c}	0.90 ± 0.05^{a}	20.13 ± 0.08^{b}	20.1 ± 1.0^{c}	9.1 ± 0.0^{e}	22.1 ± 0.5^{b}	3.5 ± 0.20^{c}

Similar letters in each column are not significantly different (Duncan multiple – range test for mean comparison at 5% level)

Table 3. Sensory properties of low – fat pizza chesses

Formulation	Appearance	Flavor	Taste	Texture	Total acceptance
1	4.0 ± 00.20^{b}	3.0 ± 00.10^{cd}	3.0 ± 66.15^{bc}	4.0 ± 00.15^{bc}	3.0 ± 66.15^{bc}
2	3.0 ± 33.20^{cd}	3.0 ± 00.10^{cd}	3.0 ± 33.10^{c}	3.0 ± 66.15^{c}	3.0 ± 00.020^{c}
3	3.0 ± 66.10^{c}	4.0 ± 00.20^{b}	4.0 ± 66.15^{a}	4.0 ± 00.15^{bc}	3.0 ± 66.25^{bc}
4	2.0 ± 33.15^{e}	2.0 ± 00.25^{d}	2.0 ± 33.15^{d}	1.0 ± 33.20^{f}	2.0 ± 33.20^{d}
5	3.0 ± 00.15^{d}	3.0 ± 00.20^{cd}	2.0 ± 66.25^{d}	3.0 ± 66.15^{c}	3.0 ± 00.15^{c}
6	2.0 ± 66.20^{de}	3.0 ± 66.15^{cb}	3.0 ± 66.10^{bc}	2.0 ± 00.25^{e}	2.0 ± 33.1^{d}
7	4.0 ± 00.20^{b}	3.0 ± 33.10^{c}	3.0 ± 33.15^{c}	3.0 ± 66.10^{c}	3.0 ± 66.15^{bc}
8	2.0 ± 33.10^{e}	3.0 ± 00.15^{cd}	2.0 ± 66.15^{d}	2.0 ± 00.25^{e}	2.0 ± 00.20^{d}
9	5.0 ± 00.20^{a}	5.0 ± 00.20^{a}	4.0 ± 66.20^{a}	5.0 ± 00.20^{a}	5.0 ± 00.25^{a}
10	3.0 ± 66.15^{c}	4.0 ± 00.15^{b}	4.0 ± 00.15^{b}	3.0 ± 00.25^{d}	3.0 ± 33.25^{bc}
11	3.0 ± 33.15^{cd}	3.0 ± 66.20^{cb}	4.0 ± 00.20^{b}	2.0 ± 00.15^{e}	3.0 ± 00.25^{c}
12	2.0 ± 00.10^{f}	3.0 ± 00.10^{cd}	2.0 ± 66.30^{d}	2.0 ± 00.25^{e}	2.0 ± 33.15^{d}
13	2.0 ± 00.15^{f}	3.0 ± 00.15^{cd}	2.0 ± 66.20^{d}	2.0 ± 00.25^{e}	2.0 ± 33.15^{d}
14	4.0 ± 33.30^{b}	4.0 ± 00.20^{b}	4.0 ± 66.20^{a}	4.0 ± 33.20^{e}	4.0 ± 00.20^{b}
15	4.0 ± 00.20^{b}	3.0 ± 66.20^{cb}	4.0 ± 00.20^{b}	4.0 ± 00.15^{bc}	4.0 ± 00.20^{b}

Similar letters in each column are not significantly different (Duncan multiple – range test for mean comparison at 5% level)

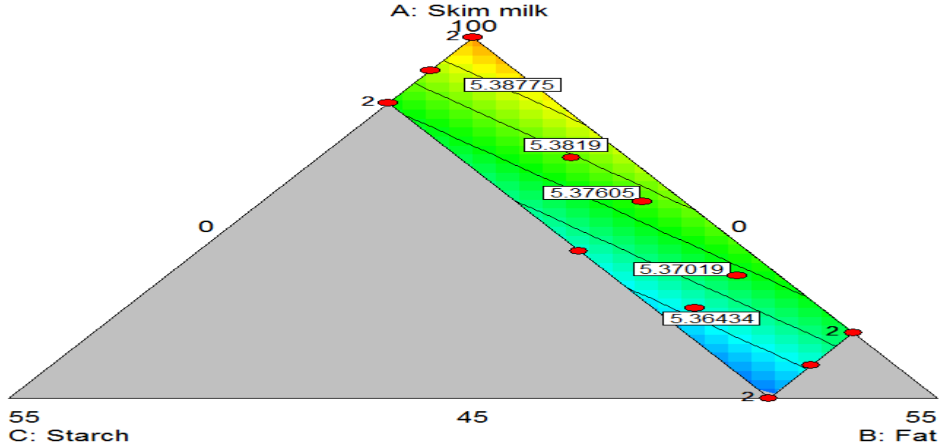

Fig. 1. Contour of pH of low – fat pizza cheese.

According to Figure 2, solid matter content of low fat pizza cheese is largely dependent on the starch content in the formulation and the variations of two other parameters had no significant effect on dry matter as dry matter content increase in this parameter ($p \leq 0.05$). According to the Codex standard, low-fat cheese is a cheese with a solid matter of 10-25% fat. On the other hand, American law defines low-fat cheese as follows: Low-fat cheese is a cheese in which the maximum fat in each unit is consumed, that is, each 50 grams equals 30 grams or 2 tea spoon. According to the standard, the fat content of high-fat mozzarella cheese should be at least 35% solid matter, provided by the Iranian Institute of Standards and Industrial Research (Jahani and Azar, 2006). As the fat content of the milk decreased, there was a significant decrease in the fat and total solids contents of the whey and in the fat content of the stretching water (Rudan *et al.*, 1999).

Figure 3, exhibits the interactive effect of independent variables on acidity that is increased as the starch content increased and low fat milk powder content decreased while fat content had insignificant effect on acidity ($p \leq 0.05$). Cheese is a fermented dairy product that throughout the production and ripening stages of this product, it is crucial to control the production of lactic acid and other acids from lactose. Acidity inhibits the growth of spoilage-producing organisms, affects the activity of coagulant during production and maturation, dissolves colloidal calcium phosphate, increases the synthesizing properties and affects the activity of enzymes during ripening. Acidity also affects the texture of the texture and the taste of the cheese (McSweeney and Sousa, 2000; Carson *et al*., 2002). Sameen (2009) reported in its study that the ripening time of cheese and the amount of acid and starter consumed had an effect on acidity, but the amount of fat had no effect on acidity changes. Pre gelatinized starch has relatively high acidity thus incorporation of this starch into the formulation of low fat pizza cheese results in increased acidity (Mounsey *et al.*, 2008[b]).

According to Figure 4, as the amount of low fat milk powder and fat increased protein content increased as the highest protein content was observed for the highest and the lowest levels of low fat milk powder and fat, respectively.

The highest and the lowest protein contents were observed for T1, T2, T3, T7, T9, T10, T12 and T13 and for T4, T6 and T8 respectively being significantly different from the control sample ($p \leq 0.05$). The variations of starch level in the formulation had no significant effect on protein content. Given the fact that low fat milk powder contains protein it increased the protein content in the cheese and on the other hand fat percentage of low fat milk powder in the low fat pizza cheese decreased as the fat content increased. Mazaheri Nasab *et al*., (2012) obtained similar results for low fat mozzarella and reported that protein content increased as fat content decreased. Hajimohammadi Farimani *et al*., (2011) observed that protein content decreased as the ratio of white cheese in the formulation of processed pizza cheese increased because of the difference in protein content between the original cheese and white cheese. Mounsey and O'Riordon, (2008[b]) showed that the inclusion of pre-gelatinized maize starch reduced the hydration of the casein as well as the thermoplastic properties of the simulated cheese and has most tender in food products where flow resistance is essential, mostly at increased temperatures.

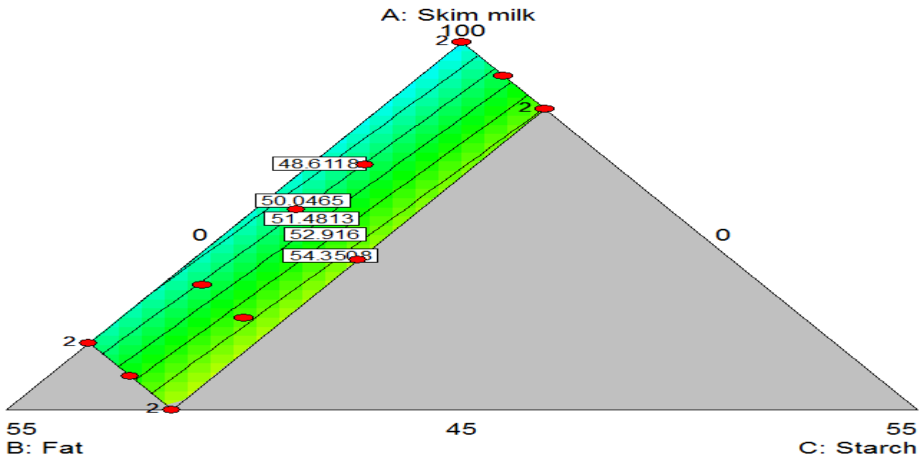

Fig. 2. Contour of solid matters of low – fat pizza cheese.

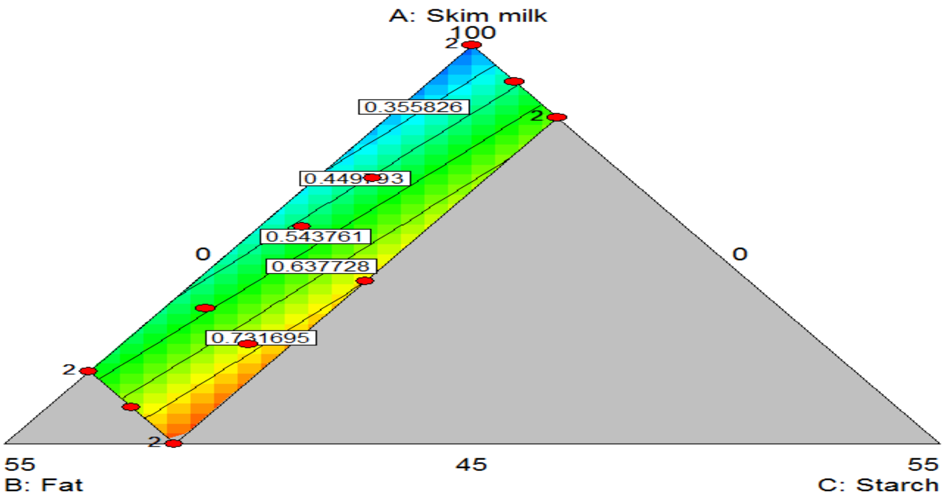

Fig. 3. Contour of acidity of low – fat pizza cheese.

Figure 5, illustrates the interactive effect of independent variables on fat content of low fat pizza cheese. According to the Figure 5 the effect of fat content in the formulation was greater than that of low fat milk powder and starch as its increased value increased the response in low fat pizza cheese. The highest and the lowest fat contained in the produced pizza cheese were found for T2 and T1 and T7 showing significant difference from the control formulation ($p \leq 0.05$). Mazaheri Nasab *et al.*, (2012) found similar results for low fat mozzarella cheese. T2 and T1 and T7 had the highest and the lowest fat content. Many properties of T1 and T7 (containing the lowest level of fat) are not satisfactory including elastic texture a different flavor than high fat counterparts, and weak functional characteristics. This cheese has very poor melt ability in spite of its better stretch ability compared to other formulations. Several studies have been conducted on the effect of fat reaction in cheese due to the consumers' interest in low fat diets. Guinee *et al*., (2001) reported significant increase in moisture, protein, ash and decrease in moisture in nonfat substance fat in dry Metter and salt in moisture in cheddar cheese caused by fat reduction.

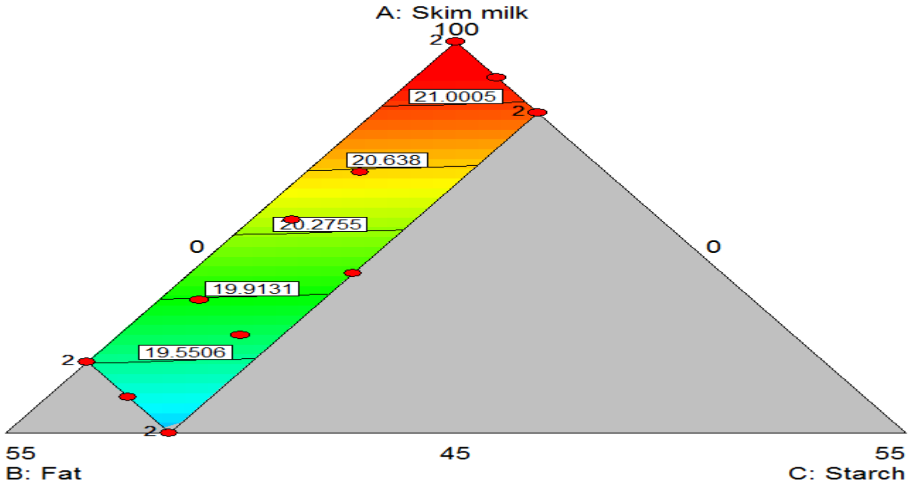

Fig. 4. Contour of protein of low – fat pizza cheese.

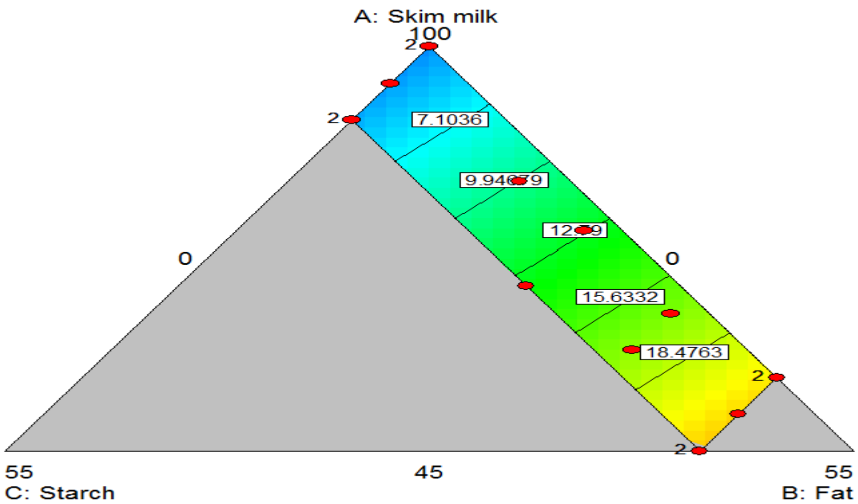

Fig. 5. Contour of fat content of low – fat pizza cheese.

According to Figure 6, stretch ability of low fat pizza cheese initially increased as low fat milk powder content increased and then it showed a decrease at maximum amounts of low fat milk powder. On the other hand, the stretch ability of the cheese initially increased followed by a decrease at minimum level of fat. Decrease in starch content in the formulation also increased the firmness of low fat pizza cheese. According to the Figure 6, the formulation containing 81% low fat milk powder, 15% fat and 3% starch showed the greatest stretch ability. The stretch ability seems to be dependent, in the first place on the amount of calcium available for generating cross links between casein chains (Chatli *et al.*, 2019). If an excessive amount of calcium is associated with caseins, the formed clot will be hard and its eyes will be increased such that there will be breakage in the measurement of stretch ability. However, insufficient amount of calcium will not form the structure and decrease the stretch ability (Fox *et al.*, 2004). According to Table 2 the stretchability decreased as the protein content decreased. Mazaheri Nasab *et al.*, (2012) reported that as the whey concentrate amount decreased the stretch ability of low fat mozzarella cheese would be reduced. The reason is the reduction in relative percentage of protein (casein) in the formulations containing a higher percentage of whey concentrate due to increased cheese moisture.

Figure 7, shows the interactive effect of independent variables on the firmness of low fat pizza cheese. According to the Figure 7, the firmness of low fat pizza cheese changed with the amount of starch and fat content. This may be due to the lubricating properties of fat and absorbing water by hydrophilic active groups in pre-gelatinized starch (Pishelmi *et al*. 2017).

Jahani and Azar, (2006) showed that the addition of whey proteins moreover reduces firmness in Mozzarella cheese. Similarly, the passage of time, which reduced the firmness and softness of most of the samples, can be related to proteolysis. It has also been found that homogenization causes texture softening due to probably related to higher humidity and higher proteolysis ratio in heterogeneous treatments. Mahasti *et al*., (2010) investigated the chemical modification of corn starch and its performance as a fat replacer in cream and observed that increased starch amount in the formulation of cream increased the firmness as the cream containing 15% starch showed the greatest firmness.

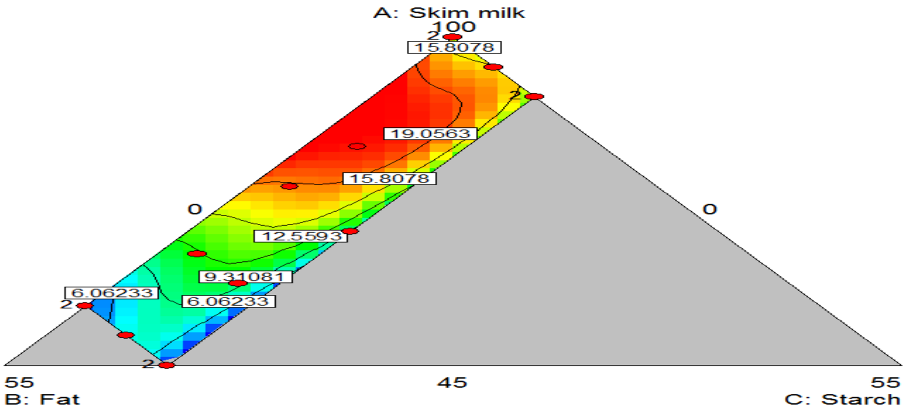

Fig. 6. Contour of stretch ability of low fat pizza cheese.

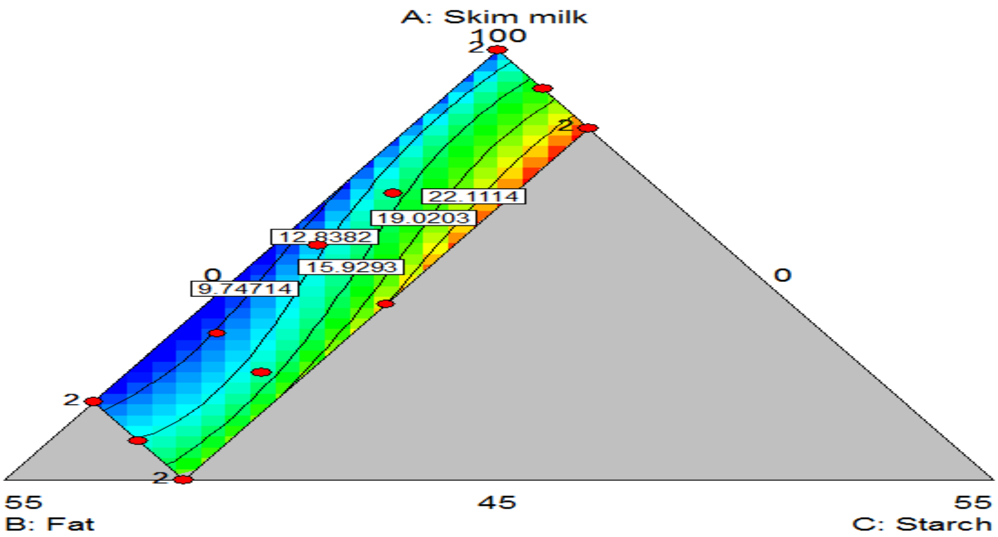

Fig. 7. Contour of firmness of low fat pizza cheese.

ANOVA showed a significant correlation at 5% between melt ability and fat content ($p \leq 0.05$). Olson and Bogenrief (1995) reported that increase in dry matter content from 18% to 45% had insignificant effect on melt ability however > 45% dry matter caused a significant increase in melt ability. Figure 8 shows the interactive effect of independent variables on the melt ability of low fat pizza cheese. As shown in the Figure8 melt ability increased as the fat content increased. Melt ability increased as low fat milk powder content decreased and starch content increased when high amount of fat was present. Low fat pizza cheese typically has poor melt ability (Fife *et al.*, 1996). Melt ability and appearance (browning) of pizza cheese are more affected than other properties (Rudan *et al.*, 1999). Higher fat content allows better cheese melting but make the shredding more difficult (Chatli *et al*., 2019). Relatively small number of fat globules in reduced fat cheeses creates a stronger network resulting in a firm and dry cheeses with poor melt ability. Mazaheri Nasab *et al.*, (2012) investigated the effect of two fat replacers on physicochemical and sensory properties of low fat mozzarella cheese and reported that the melt ability increased and decreased respectively as the amount of fat and carrageen an increased.

Hajimohammadi Farimani *et al.,* (2011) studied the optimization of processed pizza cheese formulation and observed that melt ability increased as the fat content increased. The studies showed that the undesirable properties that are exacerbated by the removal of fat from mozzarella cheese during cooking include insufficient melting, firm elastic texture, rapid crust formation, which can be explained by the function of fat cells. Appeared. Therefore, in non-fat cheese, due to the increase in protein density and their interactions, we see a firmer texture and less elasticity, which after adding fat substitutes significantly improves these defects (Malaekeh *et al*., 2014).

- ***Sensory properties of low fat pizza cheese***

Figure 9, demonstrates the interactive effect of independent variables on appearance of low fat pizza cheese for appearance initially increased as the amount of low fat milk powder and fat increased however it decreased at high levels of these two variables. Apparent desirability of this cheese decreased as an increase occurred in starch content. The highest score was given to low fat pizza cheese at low level of starch, 75% milk powder and 34% fat.

According to Figure 10, average score for flavor of low fat pizza cheese for each variable showed the highest value and at min and max levels the flavor desirability diminished. Mazaheri Nasab *et al.*, (2012) also reported that partial substitution of fat by carrageen and whey concentrate in low fat mozzarella cheese could produce a low fat product with desirable sensory properties. Starch may increase the viscosity of food environment and at maximum. level it increases the viscosity enough that will interrupt the absorption of factors contributing to the flavor. Many factors developing flavor are present in fat phase. At low levels of fat these factors decrease and on the other hand high fat contents reduce the flavor desirability (Jinjarak *et al.*, 2006).

The interactive effect of independent variables on the taste of low fat pizza cheese is presented in Figure 11. According to the Figure 11, the highest and the lowest scores for taste of the produced cheese were observed for T3, T9, T14 and T4 being, significantly different from control treatment ($p<0.05$).

At relatively low level of starch (~3%) the cheese had a desirable taste. The taste of this cheese showed no certain trend with the variations of fat and low fat milk powder contents as 22.5, 34 and 15% fat and 75, 82 and 64% low fat milk powder were given the highest score for taste.

Figure 12, shows the interactive effect of independent variables on the texture of low fat pizza cheese. According to the Figure 12 the score for texture initially increased as all three components increased however at high levels of these components increased starch content in the formulation makes the food firm through increasing the viscosity, while fat having lubricating properties could soften the food (Jinjarak *et al.*, 2006). Duggan *et al.*, (2008) reported that increased starch content strengthened the texture of cheese while high levels of starch resulted in cheese firmness thereby reducing its desirability.

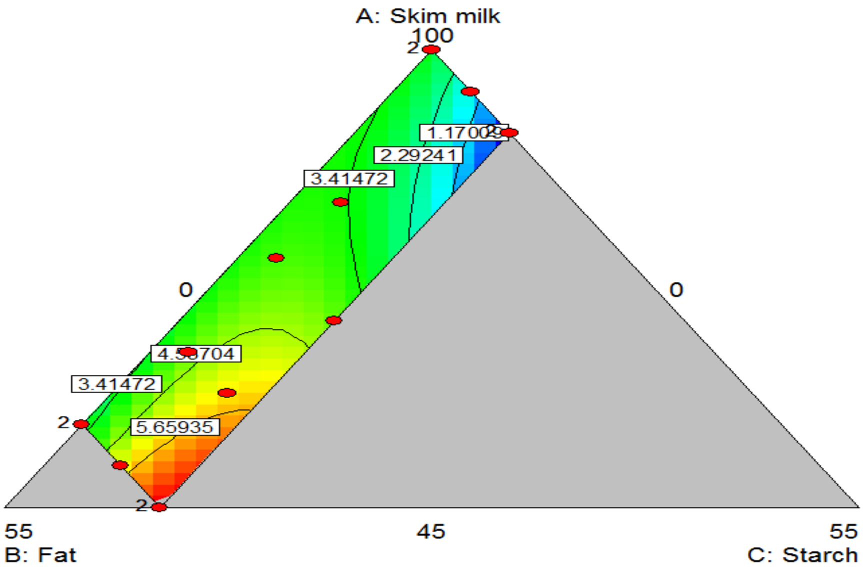

Fig. 8. Contour of melt ability of low – fat pizza cheese.

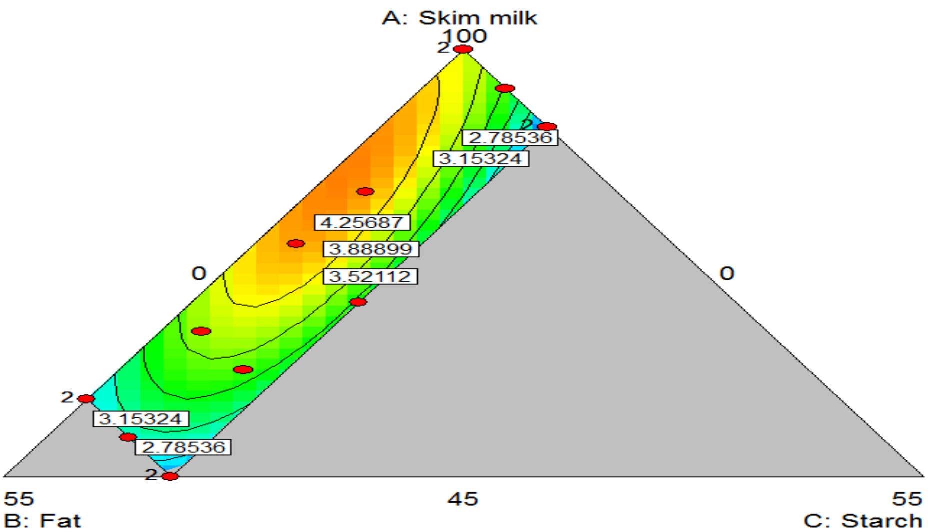

Fig. 9. Contour of appearance of low-fat pizza cheese.

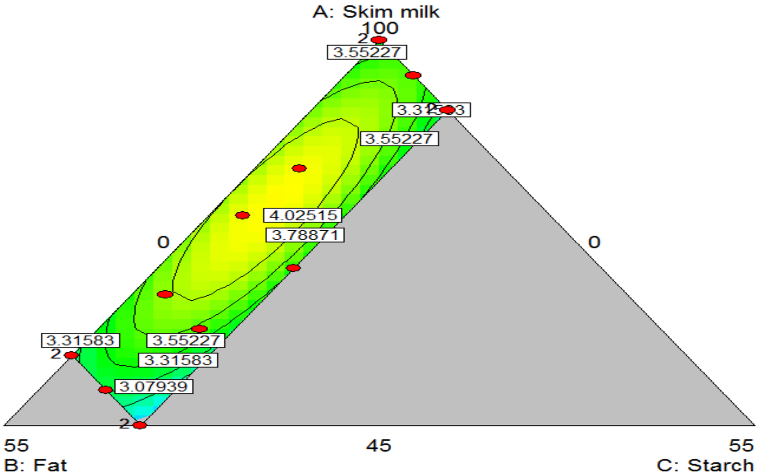

Fig. 10. Contour of flavor of low fat pizza cheese.

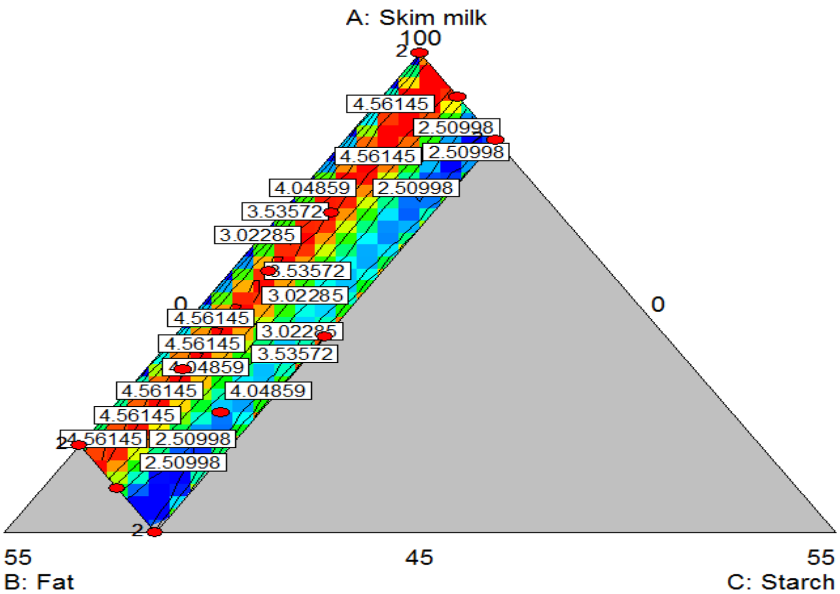

Fig. 11. Contour of taste of low fat pizza cheese.

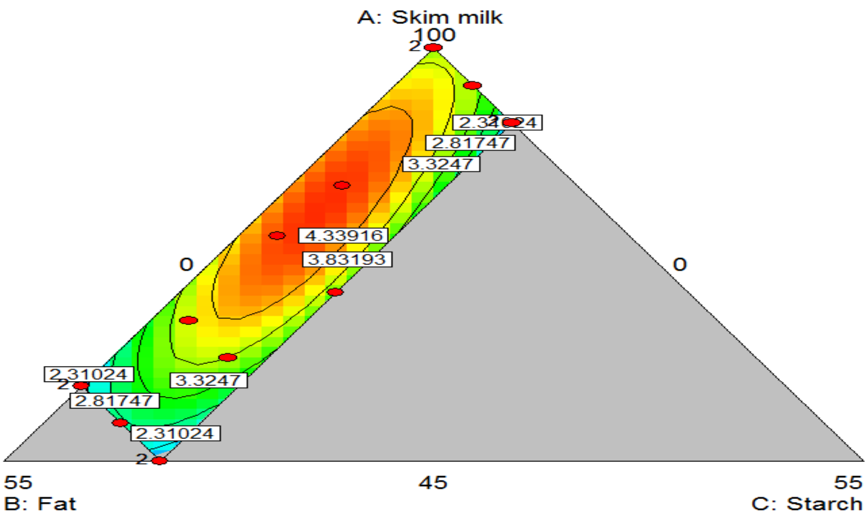

Fig. 12. Contour of texture of low fat pizza cheese.

Figure 13, indicates the interactive effect of independent variables on total acceptance of low – fat pizza cheese. According to the Figure 13 total acceptance initially increased as the amounts of low – fat milk powder and fat contents increased while at high levels of these two variables total acceptance decreased. Total acceptance diminished as starch content increased.

The panelist reported the reason for this result that can be related more favorable texture in low fat pizza cheeses. The greatest acceptability of low fat pizza cheese was observed at low level of starch ~80% low fat skim milk powder and 34% fat.

In order to confirm the results of this research, Pishelmi *et al.* (2017) used pre-gelatinized starch in the formulation of low-fat stirred yogurt and reported that the overall acceptance score increased with increasing pre-gelatinized starch content. Mahasti *et al.,* (2010) observed that partial substitution of cream fat by modified corn starch might improve sensory properties of the product. Sadradalabayi *et al*., (2014) showed that total acceptance of the sample containing 1% of menu and diglyceride was higher than other samples, which is higher due to the softness of the valence sample.

- *Optimization of formulation*

In this study in order to optimize the formulation of low fat pizza cheese, the dependent variables were defined following the examination of the respective standards and obtained experiences. Thus melt ability, stretch ability and sensory properties were maximized; firmness was minimized; and acidity (0.50-0.47) and dry matter (40-50) were set in a certain range. According to the defined limits for dependent variables optimization carried out by numeral optimization method. A formulation containing 67.56% low – fat milk powder 27.93% fat and 4.5% starch was found optimal. Melt ability, acidity, stretch ability, firmness, solid matters, flavor, texture, and total acceptance were 4.41(mm), 0.485, 15.43(cm/s), 12.82(N), 51.51(%), 4.14, 4.58 and 4.14 respectively with total acceptance of 85%. In general, increased desirability increases the possibility of obtaining response. In next step the best point (formulation) for physicochemical properties was prepared and evaluated in order to keep the accuracy of results. Melt ability acidity stretch ability firmness solid matters flavor, texture and total acceptance were 4.08, 0.46, 13.91, 14.11, 49.68, 3.85, 4.26, and 3.78 respectively. The closeness of the estimated and measured values for the optimized formulation indicates the fitness of selected models and their high predictability. Small difference found between the predicted responses by software and observed in the laboratory may partly be due to equipment and measurement error. Figure 14 shows the optimization process where optimum conditions exhibit acceptability of about 80%. The treatment consisting of 67.56% low fat milk powder, 27.93% fat and 4.5% starch was found as the optimal formulation.

Conclusion

In this study mixture statistical design was successfully applied for evaluation and optimization of the formulation of low fat pizza cheese. All physicochemical properties of the produced cheese were significantly affected by the mixture components. Second order model for melt ability and sensory properties, cubic model for stretch ability and firmness and linear model for other responses showed more accuracy than other models. A formulation containing 67.56% low fat milk powder 27.93% fat and 4.51% starch was found optimal. Melt ability, acidity, stretch ability, firmness, solid matters, flavor, texture and total acceptance were 4.08 (mm), 0.46%, 13.91(cm/s), 14.11(N), 49.68(%), 3.85, 4.26 and 3.78 respectively. The closeness of estimated and measured values for the optimized formulation indicates the fitness of selected models and their high predictability.

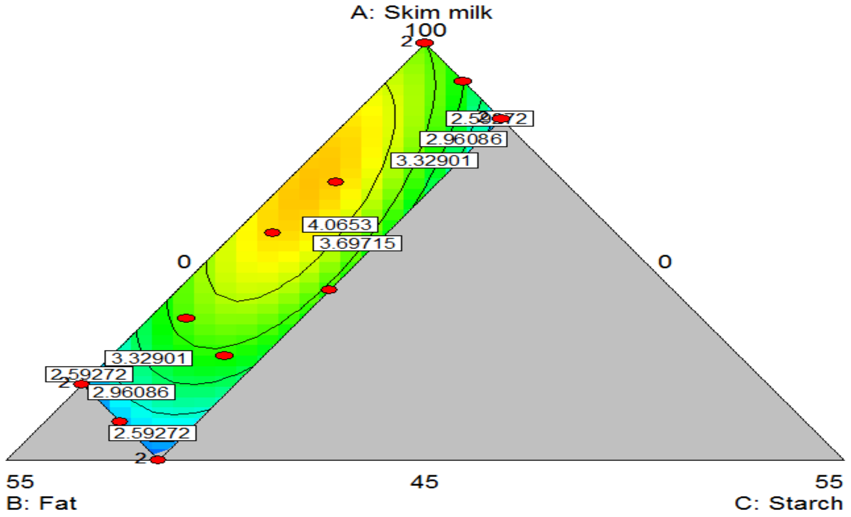

Fig. 13. Contour of total acceptance of low – fat pizza cheese.

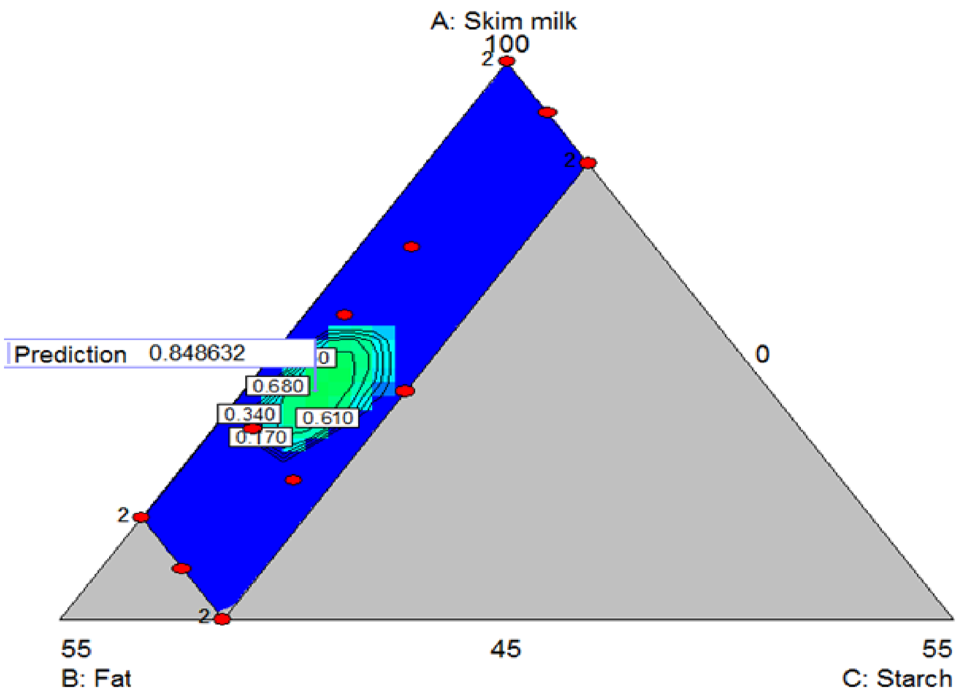

Fig. 14. Contour of overlapped physicochemical properties of low – fat pizza cheese.

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