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OPTIMISATION OF ALMOND MILK PRODUCING USING RESPONSE SURFACE METHOD

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ABSTRACT

The purpose of this study was to find the optimal production's condition of almond milk. By this purpose it was determined dilution fold (3–7) and dilution temperature (25–80 °C) as producing parameter by pro-test. Totally 13 milk was produced. Under these conditions, effects of dilution fold and dilution temperature were investigated on the chemical compositions, energy and sensory properties of producted almond milks by Responce surface Method. According to results, dry matters of almond milks were determined as averagely 12.77%; ash 0.43%, protein 3.21%; fat 6.85%; carbohydrate 2.44%. Results of energy values were changed between 67 cal.100-1 mL and 103 cal.100-1 mL. Produced almond milk at 71.2 °C dilution temperature and 3 fold dilution, it has been the maximum desirability as 94%.

Key words: Almond Milk, Energy, Responce Surface Method, Sensory Properties

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INTRODUCTION

The healthy nourisment is one of the most important factor on people, who want to live healthly, powerfully and successefuly (Anonymous, 2001; Hanry and Chapman, 2002; Anonymous, 2006). Nowadays food, which can be supporter to lead a healthy life, are interested by people. These kinds of foods have an important role against diseases (Kök Taş, 2012) and the almond (*Prunus amygdalus)* welcomes us by high nutrition compounds (Ahmad, 2010). The consumption of almond regularly can help to reduce blood sugar and reduce the risk of cardiovascular diseases (Kendall et al., 2007). Almond has a very beneficial effect to human body so it is classified into the functional food groups (Guven and Gulmez, 2006).

In the last few years, plant – based beverages such as almond milk, soy milk, peanut milk, etc, start to become a good alternative non – diary beverage in Europe and USA (Dhakal, Liu, Zhang, Roux, Sathe, Balasubramaniam, 2014). Last studies have shown that, almond milk is prefered especially by people who suffer from diabetes, coeliac artery compression syndome, hypersensitive to cow milk and lactose intolerance (Anonymous, 2013; Lacono, Lospalluti, Licastro, Scalici and Pediatria, 2008; Salpietro, 2005). Almond milk is also rich in essential and non-essential nutrients like α-tocopherol, essential fatty acids, dietary fiber, and a wide range of other phytochemicals. The consumption of almond milk can also be linked to reduction of the risk of coronary heart disease by decreasing the plasma LDL cholesterol level (Chen, Milbury, Lapsley and Blumberg, 2005).

In our study, we have focused on producing almond milk, determining the effect of dilution fold and dilution temperature, and finding optimisation conditions for the processing. We have used the Response surface Method (RSM) to find these conditions. Response surface Method (RSM) is a great appliance to detect the optimal conditions during the food processing (Thompson, 1982). The main advantage of RSM is its capability to reduce the number of experimental factors required to maintain adequately information to get statistical result (Youn and Chung, 2011).

MATERIALS AND METHODS

All the materials on this study which are, raw almond and potable water, were purchased from the local market in Hatay, Turkey. All chemical materials were analitical purity.

Preparation of Almond Milk

Response surface Method (RSM), which was a kind of experimental design, was used on preparation of almond milk. The dilution fold as 3 to 7 and dilution temparature as 25 to 80 ^{0}C were determined as two independent variables (Myers and Montgomery, 2002). The Experimental desing for Response surface Method was shown in Figure 1 and the flow chart for almond milk was shown in Figure 2.

Variable	**Code**	**–α**	**-1**	**0**	**+1**	**+ α**	
Dilution Fold	X_1	3.0	3.60	5.0	6.40	7.0	
Dilution Temp.	X_2	25.0	33.0	52.5	72.0	80.0	
–α	-1.412				+1.412		+α

Samples	**X_1**	**X_2**
1	6.4	72.0
2	5.0	52.5
3	6.4	33.0
4	5.0	80.0
5	5.0	52.5
6	5.0	52.5
7	7.0	52.5
8	3.6	33.0
9	5.0	25.0
10	3.0	52.5
11	5.0	52.5
12	3.6	72.0
13	5.0	52.5

Figure 1. Experimental desing for RSM

Raw Almond (250 grams)
↓
Soaking (overnight)
↓
Dehulling
↓
Blending
↓
Filtration
↓
Almond milk
↓
Pasteurization (80 – 85 ^{0}C for 15 min)

Figure 2. Flow chart for Almond Milk Preparation

Chemical Compositions

Dry matter, ash, crude protein were determined according to standard methods (Anonymous, 1990; Anonymous, 1995). Fat of almond milks was determined by gerber method (Kurt et al., 1996). The amounts of total carbohydrate were calculated by subtracting the amounts of moisture, crude protein, total fat and ash from 100 (Gibson, 1990). Energy values of almond milks were calculated by addition supplied enegry values of protein, fat and carbohydrate (Gibson, 1990).

Sensory Properties

Sensory properties were analysed by 50 member untrained panel. Panelists graded 1 to 9 points about appearance, color, taste, consistence, odor and acceptability. According to hedonic scale: 9= extremely like and 1= extremely dislike for the assessment of appearance, color, taste, consistence, odor and acceptability (Martinez - Flores et al., 2005).

Optimisation

In this study, the optimisation was made according to numeric optimisation method of design expert program. This method was based on the basic of desirability function (Myers and Montgomery, 2002).

Statistical analysis

The response surface method's two variable and three level central composit design was used to determinate the effects of independent variables on dependent variables for the analysis of variance. A regression equation has been determined to show relations between variables. Dilution fold and dilution tempareture has been determined as independent variables for experimental design. Design expert packaged software of version 6.0 program was used for statistical analysis (Montgomery, 2001; Montgomery and Mayers, 2002).

RESULTS AND DISCUSSIONS

Chemical compositions

Proximate compositions of almond milks were shown in Table 1. Almond milks comprised 12.77±0.03% dry matter, 0.43±0.01% ash, 3.21±0.02% crude protein, 6.85±0.02% fat, 2.44±0.01% carbohyrate. All results were given on average.

Table 1. Proximate compositions of almond milks

Samples	Dry matter (%)	Ash (%)	Protein (%)	Fat (%)	Carbohydrate (%)	Energy (cal.100^{-1} mL)
1	13.11±0.03	0.45±0.01	3.02±0.01	6.40±0.02	3.26±0.02	82±0.01
2	15.11±0.03	0.52±0.03	4.21±0.03	7.30±0.01	2.49±0.02	92±0.02
3	11.70±0.04	0.38±0.01	2.85±0.02	6.80±0.02	1.68±0.01	79±0.01
4	14.62±0.02	0.48±0.01	3.93±0.01	6.50±0.02	3.73±0.02	89±0.01
5	12.67±0.03	0.43±0.02	2.93±0.01	7.50±0.03	1.82±0.02	86±0.02
6	10.95±0.04	0.35±0.02	2.70±0.02	6.40±0.02	2.05±0.02	76±0.02
7	9.75±0.02	0.32±0.01	1.78±0.02	5.80±0.03	2.10±0.02	67±0.03
8	15.10±0.04	0.50±0.02	4.19±0.03	7.40±0.01	3.91±0.01	99±0.01
9	9.90±0.02	0.34±0.01	1.96±0.02	6.50±0.03	1.70±0.02	73±0.02
10	16.50±0.03	0.58±0.03	4.60±0.02	8.00±0.01	3.37±0.02	103±0.01
11	10.80±0.04	0.35±0.02	2.69±0.01	6.50±0.03	1.36±0.02	74±0.02
12	15.45±0.04	0.54±0.01	4.22±0.02	7.60±0.02	3.14±0.02	97±0.02
13	10.35±0.06	0.35±0.02	2.65±0.03	6.30±0.02	1.15±0.02	71±0.03
Average	**12.77±0.03**	**0.43±0.01**	**3.21±0.02**	**6.85±0.02**	**2.44±0.01**	**84±0.01**

Dry matters of almond milks were determined between 9.75±0.02% and 16.50±0.03% and were determined as averagely 12.77±0.03%. According to analysis of variance, the effect of dilution fold has been determined significantly on dry matters ($p<0.01$). Increasing of water content caused to reduce the dry matter on almond milks. The linear regression model of relation between two independent factors (dilution fold and dilution temperature) had been shown by an equation with coded factories and real factors for dry matter.

$$D.M\ (C.F) = 12.63 - 2.72\ (A) + 1.62\ (B)$$
$$D.M\ (R.F) = 16.728 - 1.360\ (A) + 0.054\ (B) \qquad \text{(Eq. 3.1)}$$

D.M: Dry matter, C.F: Coded factor, R.F: Real factor, A: Dilution fold, B: Dilution temperature

It is shown that dilution fold was more effective than the dilution temperature and it has been determined as significant (p<0.01). Three dimentional graphic of response surface of dilution fold and dilution temperature were shown in Figure 3. According to Figure 3, increasing of dilution fold has caused a decrease in of dry matter linearly.

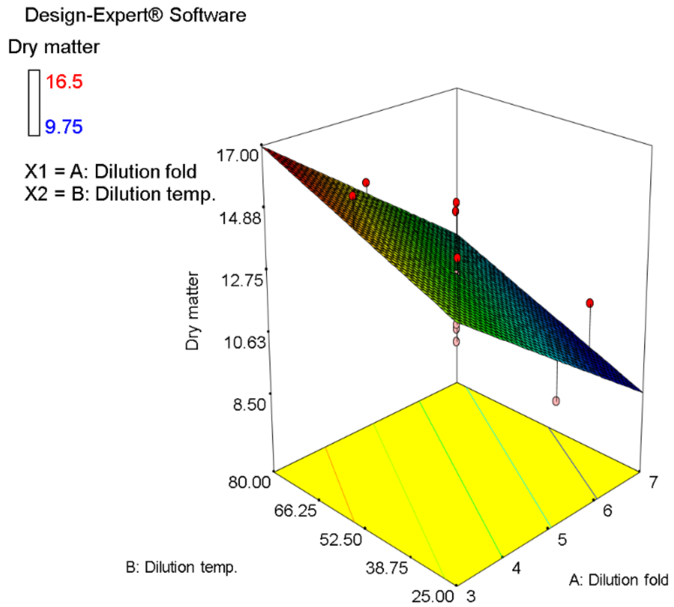

Figure 3. The effect of dilution fold and dilution temperature on dry matter.

Ash of almond milks was determined between 0.32±0.01% and 0.58±0.03% and as average 0.43±0.01%. The effect of dilution fold has been determined significantly on ash (p<0.05). The linear regression model of relation between two independent (dilution fold and dilution temperature) had been shown by an equation with coded factors and real factors for ash.

$$Ash\ (C.F) = 0.43 - 0.10(A) + 0.06(B)$$
$$Ash\ (R.F) = 0.58 - 0.051(A) + 0.002(B) \qquad \text{(Eq. 3.2)}$$

C.F: Coded factor, R.F: Real factor, A: Dilution fold, B: Dilution temperature

Three dimentional graphic of response surface of dilution fold and dilution temperature had been shown in Figure 4. According to Figure 4, the increasing of the dilution fold had caused a decreasing in ash value.

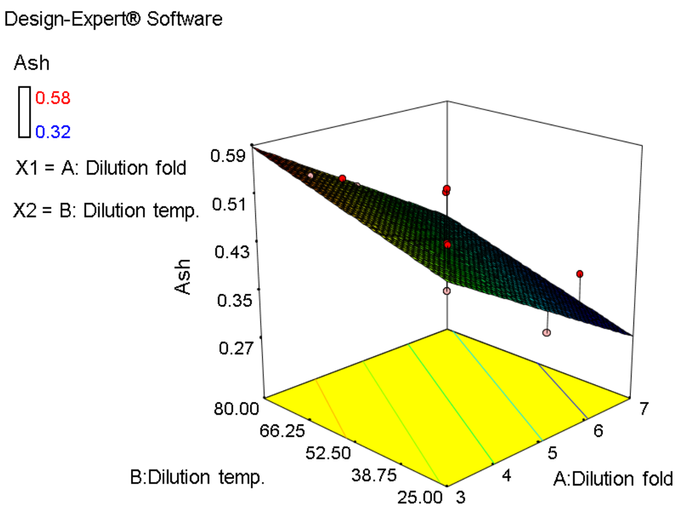

Figure 4. The effect of dilution fold and dilution temperature on ash.

Proteins of almond milks were determined between 1.78±0.02% and 4.60±0.02% and as average 3.21±0.02%. The effect of dilution fold has been determined significant ($p<0.05$). The linear regression model of relation between two independent factors (dilution fold and dilution temperature) had been shown by an equation with coded factors and real factors for protein.

$$Protein\ (C.F)= 2.99–1.17(A)+0.54(B)+0.40(A^2)+0.19(B^2)+0.08(AB)$$
$$Protein\ (R.F)= 8.37–1.65(A)+0.009(B)+0.10(A^2)+0.0002(B^2)+0.001(AB) \quad \text{(Eq. 3.3)}$$

C.F: Coded factor, R.F: Real factor, A: Dilution fold, B: Dilution temperature

Three dimentional graphic of response surface of dilution fold and dilution temperature had been shown in Figure 5. According to Figure 5, increasing of the dilution fold had caused a decrease in protein value. This is similar with Figure 3 and Figure 4.

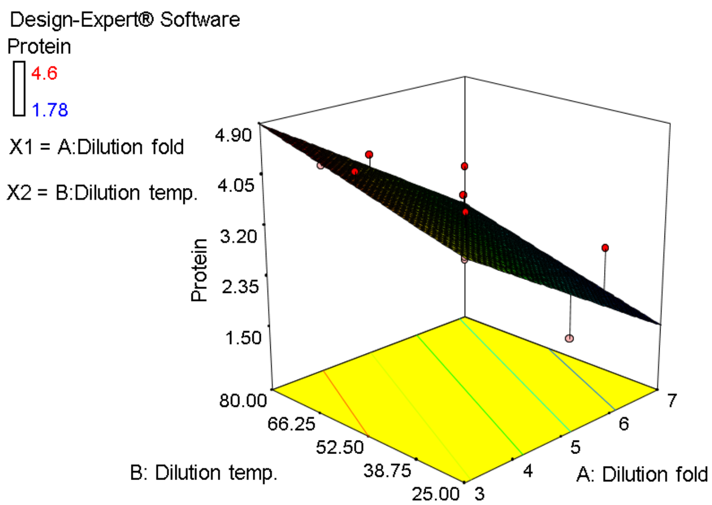

Figure 5. The effect of dilution fold and dilution temperature on protein.

Fat amounts of almond milks were determined between 5.80±0.03% and 8.00±0.01% and as average 6.85±0.02%. The effect of dulition fold has been determined significant on fat ($p<0.01$). The linear regression model of relation between two independent factors (dilution fold and dilution temperature) had been shown by an equation with coded factors and real factors for fat.

$$Fat\ (C.F) = 6.85 - 0.87(A) - 0.039(B)$$
$$Fat\ (R.F) = 9.098 - 0.437(A) - 0.001(B) \qquad \text{(Eq. 3.4)}$$

C.F: Coded factor, R.F: Real factor, A: Dilution fold, B: Dilution temperature

Three dimentional graphic of response surface of dilution fold and dilution temperature had been shown in Figure 6. According to Figure 6, increasing of the dilution fold had caused a decrease in fat value as linearly.

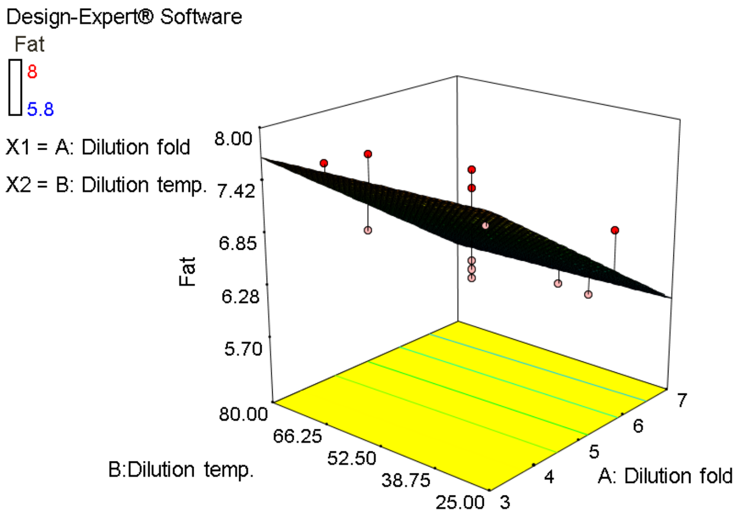

Figure 6. The effect of dilution fold and dilution temperature on fat.

Carbohydrate amounts of almond milk were determined between 1.15±0.02% and 3.91±0.01% and as average determined 2.44±0.01%. According to result of variance analysis, the effect of dilution fold has been significant ($p<0.05$). The linear regression model of relation between two independent (dilution fold and dilution temperature) had been shown by an equation with coded factors and real factors for carbohydrate.

$$Carbohydrate\ (C.F) = 2.38 - 0.69(A) + 0.71(B)$$
$$Carbohydrate\ (R.F) = 2.94 - 0.35(A) + 0.024(B) \qquad \text{(Eq. 3.4)}$$

C.F: Coded factor, R.F: Real factor, A: Dilution fold, B: Dilution temperature

Three dimentional graphic of response surface of dilution fold and dilution temperature had been shown in Figure 7. According to Figure 7, increasing of the dilution fold had caused a decrease in carbohydrate value as linearly.

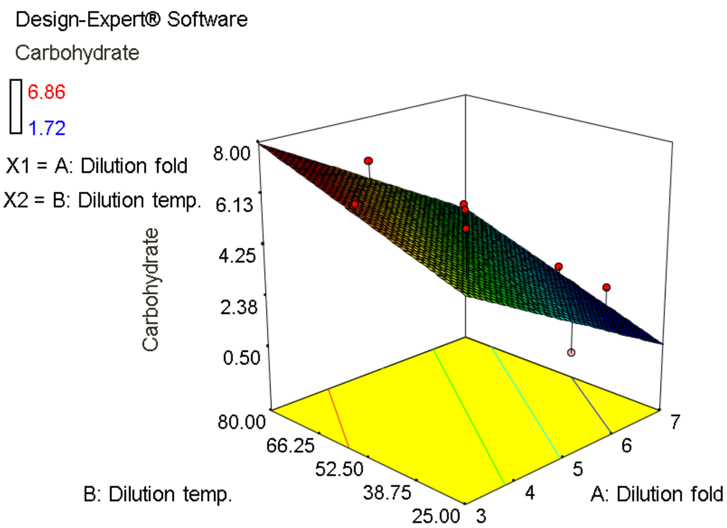

Figure 7. The effect of dilution fold and dilution temperature on carbohydrate.

As we can see from the all results of chemical components, the dilution fold has an big role about decreasing the values. Therefore, it is thought that the solubility of organic and inorganic materials in water may effect the scores. Results of energy values were changed between 67 cal.100^{-1} mL and 103 cal.100^{-1} mL. According to analysis of variance, the effect of dilution fold has been determined significantly on energy values ($p<0.01$).

Each of energy values of almond milks were calculated by a formula that was shown below;

*Energy (cal/*100*mL) = (*4 ** protein) +* (4 ** carbohydrate) +* (9 ** fat)* (Eq. 3.5)

Sensory properties

The sensory properties of almond milks were shown in Table 2.

Table 2. Sensory properties of almond milks

Samples	Apperance	Color	Consistence	Taste	Odor	Acceptability
1	7.60 ± 0.01	7.70 ± 0.02	7.10 ± 0.01	6.50 ± 0.03	6.30 ± 0.02	6.60 ± 0.01
2	6.30 ± 0.02	6.70 ± 0.02	6.30 ± 0.02	6.20 ± 0.03	6.20 ± 0.02	6.70 ± 0.02
3	7.30 ± 0.01	7.50 ± 0.03	6.50 ± 0.01	6.30 ± 0.02	6.20 ± 0.01	6.10 ± 0.01
4	6.20 ± 0.03	6.80 ± 0.03	6.30 ± 0.03	6.10 ± 0.03	5.80 ± 0.03	6.20 ± 0.03
5	6.70 ± 0.02	7.30 ± 0.01	6.10 ± 0.02	6.10 ± 0.02	6.00 ± 0.02	6.10 ± 0.02
6	8.10 ± 0.01	8.20 ± 0.01	8.20 ± 0.01	5.70 ± 0.01	6.40 ± 0.01	6.50 ± 0.01
7	8.00 ± 0.02	8.00 ± 0.01	7.00 ± 0.02	6.00 ± 0.01	5.80 ± 0.02	6.20 ± 0.02
8	8.70 ± 0.02	8.50 ± 0.02	8.50 ± 0.02	7.70 ± 0.03	7.00 ± 0.02	7.80 ± 0.02
9	8.10 ± 0.01	8.20 ± 0.01	7.20± 0.02	6.40 ± 0.01	6.40 ± 0.01	6.50 ± 0.02
10	7.70 ± 0.01	7.60± 0.01	7.30 ± 0.03	6.70 ± 0.01	7.10 ± 0.02	7.20 ± 0.03
11	7.60 ± 0.04	7.11± 0.04	7.10 ± 0.03	7.50 ± 0.05	7.70 ± 0.04	7.60 ± 0.04
12	8.10 ± 0.01	7.80 ± 0.04	7.70 ± 0.04	6.70 ± 0.02	7.00 ± 0.01	7.70 ± 0.01
13	6.70 ± 0.03	6.80 ± 0.05	6.50 ± 0.03	6.00 ± 0.03	7.10 ± 0.03	6.80 ± 0.03
Average	**7.46± 0.01**	**7.55± 0.02**	**7.06± 0.02**	**6.45± 0.02**	**6.54± 0.01**	**6.77± 0.02**

Apperance

The apperance scores of almond milks were given in Table 2. According to Table 2, results changed between 6.20±0.03 (number 4) and 8.70±0.02 (number 8) and as averagely 7.46±0.01 was determined. In terms of variance analysis, dilution fold and dilution temperature did not have an effect on scores and this effect has been found insignificant ($p>0.05$).

Color

The color scores of almond milks were shown in Table 2. Scores ranges were between 6.70±0.02 (number 2) and 8.50±0.02 (number 8) and as average 7.55±0.02. Dilution fold and dilution temperature has been insignificant ($p>0.05$). These two variable factors (dilution fold and dilution temperature) did not have any effect on the color of almond milks.

Consistence

The consistence scores of almond milk were summarized in Table 2. Scores changed 6.10±0.02 (number 5) and 8.50±0.02 (number 8) and as average it was 7.06±0.02. In terms of variance analysis, dilution fold and dilution temperature did not have an effect to scores and this effect has been found insignificant ($p>0.05$).

Taste

The taste scores of almond milks were shown in Table 2. According to Table 2. Scores have shown difference between 5.70±0.01 (number 6) and 7.70±0.03 (number 8) and as average it was 6.45±0.02. Dilution fold and dilution temperature has been insignificant ($p>0.05$). These two variable factors (dilution fold and dilution temperature) did not have any effect on the taste of almond milks.

Odor

The odor scores of almond milks were summarized in Table 2. Resutls have a range between 5.80±0.01 (number 7) and 7.70±0.04 (number 11) and as average it was 6.54 ±0.01. According to variance analysis, dilution fold has an effect on odor and it was found significant ($p<0.05$). Increasing of water content caused to reduce the odor of almond milks. The linear regression model of relation between two independent factors (dilution fold and dilution temperature) has been shown by an equation with coded factors and real factors for odor

$$\begin{aligned} \mathit{Odor(CF)} &= 6.55 – 0.59(A) - 0.14(B) \\ \mathit{Odor(RF)} &= 8.27 – 0.30(A) - 0.0005(B) \end{aligned} \qquad \text{(Eq 3.6)}$$

CF: Coded factor, RF: Real factor, A: Dilution fold, B: Dilution temp.

Three dimentional graphic of response surface of dilution fold and dilution temperature have been shown in Figure 3. According to Figure 3, increasing of dilution fold has caused a decrease in odor values as linearly.

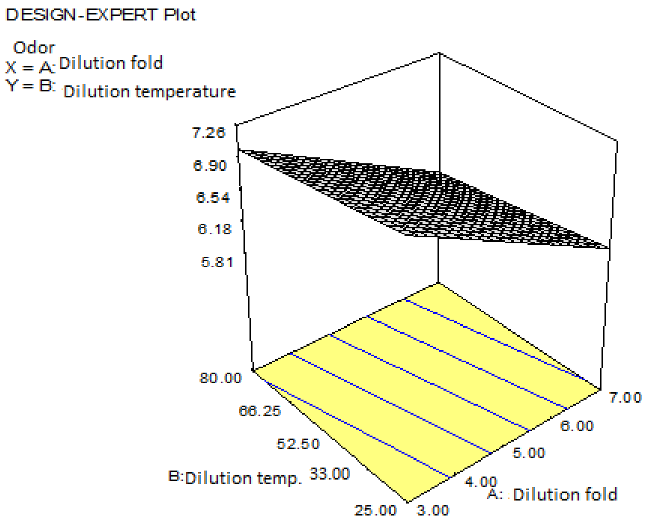

Figure 8. The effect of dilution fold and dilution temperature on odor.

Acceptability

The acceptability scores of almond milks were shown in Table 4. According to table, Acceptability scores were a range between 6.10±0.01 (number 3) and 7.80±0.02 (number 8), as average it was 6.77±0.02 . In variance analysis, it was shown that dilution fold has an effect on acceptability of almond milk and this has been found significant ($p<0.01$). The linear regression model of relation between two independent (dilution fold and dilution temperature) has been shown by an equation with coded factors and real factors for acceptability.

$$Acceptability\ (CF) = 6.77–0.75(A)-0.0003(B)$$
$$Acceptability\ (RF) = 8.85–0.37(A)-0.0002(B) \qquad \text{(Eq. 3.7)}$$

CF: Coded factor, RF: Real factor, A: Dilution fold, B: Dilution temp.

Three dimentional graphic of response surface of dilution fold and dilution temperature have been shown in Figure 9. According to Figure 9, increasing of dilution fold has caused a decreased in acceptability values as linearly.

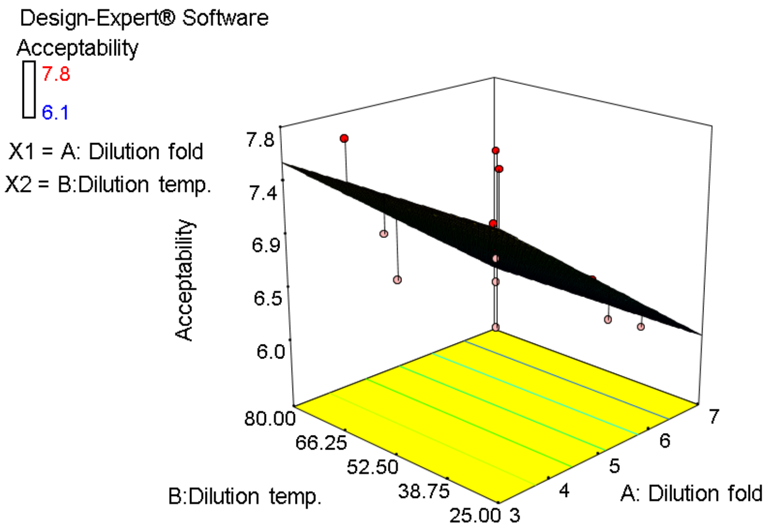

Figure 9. The effect of dilution fold and dilution temperature on acceptability.

It is shown that, dilution fold, has no effects on the sensory properties except odor and acceptability. It is thought for especially odor, the volatile components of almond milk are caused by water solubility.

Optimisation

The optimisation of almond milks was analysed by design expert packaged software of version 6.01 programme and optimal conditions were determined. Optimisation was determined by using maximum values of fat%, protein%, dry matter% and acceptability scores in the range of independent variables values. The use of values was shown in Table 3 for optimisation model. After numeric optimisation, optimal producing conditions were given in Table 4.

Table 3. The using of values for optimisation of almond milks

Variances	Target	Minimum Value	Maksimum Value
Dilution fold		3	7
Dilution temp.		25 ^{o}C	80 ^{o}C
Fat	Maksimum	5	8
Protein	Maksimum	1.78	4.6
Dry matter	Maksimum	9.75	16.5
Acceptability	Maksimum	6.1	7.8

Table 4. Optimal producing conditions of almond milks

Variance	Optimal Condition
Dilution fold	3
Dilution temperature	71.2 ^{o}C
Fat	7.76
Protein	4.60
Drymatter	16.50
Acceptability	7.52
Desirability	0.94

Almond milk was optimisated as 7.76% of fat, 4.60% of protein, 16.50% of dry matter, 71.2 ^{o}C dilution temperature and 3 fold dilution. Desirability was found 94%. Three dimentional graphic of response surface of dilution fold and dilution temperature have been shown in Figure 10.

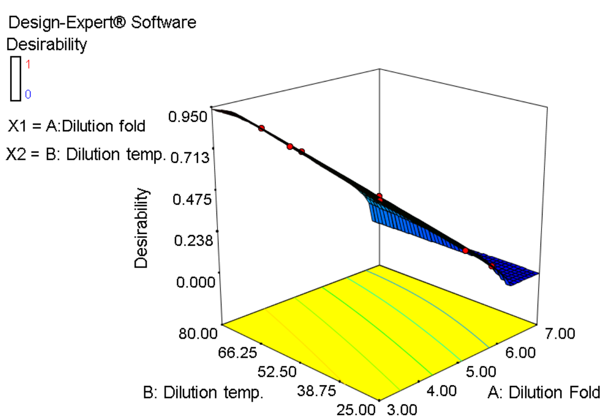

Figure 10. The effect of dilution fold and dilution temperature on desirebility.

CONCLUSION

In this study, we purposed to produce almond milk, to determine the effect of dilution fold and dilution temperature on composition of almond milks and to determine of optimal conditions for almond milk production. Produced almond milk at 71.2 ^{o}C dilution temperature and 3 fold dilution, it got the maximum desirability as 94%. Increasing of dilution fold, caused quickly to reduce the desirebility. It can be concluded that almond milk can be a good alternative of cow milk due to absence of lactose and allergens and with better nutritional as well as sensory profile. Since it was a pilot scale study for the non dairy milk alternative, further modifications with respect to addition of emulsifiers, sweeteners and other additives may be carried for the commercialization of product.

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