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# FORMULATION OPTIMIZATION OF FUNCTIONAL YOGURTS FORTIFIED WITH ALMOND, OAT, HONEY AND TART CHERRY EXTRACT

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## ABSTRACT
Using a D-optimal mixture design methodology, a powder mixture of four most well-known functional food ingredients (almond, Montmorency tart cherry extract, honey crunchy, and oat flour) was formulated for adding to yogurt by consumers, just before consumption. With this technique, consumers are given the opportunity to produce fresh stirred yogurts, compatible with their taste and diet, whenever they need. The contour plots were drawn for the quality attributes of the formulated yogurts, including pH, moisture content, syneresis, color indices, textural and sensorial properties using polynomial models. The results showed that almond powder was the most effective component, followed by the tart cherry extract, honey and oat, respectively. Formulation optimization based on technological, nutritional and sensory attributes confirmed that the overall optimum zone with a desirability of 0.912 was at 80% almond, 6.30% tart cherry extract, 6.05% honey and 7.65% oat. Besides all other nutritional and functional bioactive components, this proposed optimized powder formula would have approximately 17.13% crude fiber, 29.59% neutral detergent fiber (NDF) and 25.67% acid detergent fiber (ADF) and can be served as a good source of bio-functional and prebiotic supply.

**KEYWORDS**: Almond, Formulation, Functional, Honey, Oat, Tart Cherry, Yogurt

## INTRODUCTION
In recent years, the demand for functional foods has increased due to the raised prevalence of chronic diseases and improved public awareness (Aryee and Boye, 2015). Probiotics, prebiotics and synbiotics as functional foods have an important role in health promotion and disease prevention (Frei *et al.*, 2015). On the other hand, with the change in consumer lifestyles and the reduction in the time available to spend for a full meal, production of healthy and diversified snacks with high nutritional value has become a challenge for both researchers and industry scientists in developing new products. Snacks are also called Between Meal Eating Episodes (BMEE). These products can be salty or spicy like nuts, crisps and pretzels. They can be sweet like cakes, yogurts, fruit, biscuits, and confectionery products. These products also can include beverages such as fruit juices, squashes, carbonated soft drinks or milk. However, development of functional foods or snack products is a complex process with success factors that are somewhat different from the development of traditional food products (Khan *et al.*, 2013). Yogurt is a good choice for the application of prebiotic and probiotic ingredients and many studies have been conducted in this field (Tian *et al.*, 2015). Almond (*Prunus amygdalus* L.) is a rich source of several essential ingredients such as vitamin E, minerals, ω-6 and ω-9 fatty acids, arginine, magnesium and phytochemicals that may contribute to its health benefits (Mahmood, 2015). In addition, indigestible polysaccharides present in almond can supply high prebiotic potential of this fruit (Liu *et al.*, 2014). Honey is another familiar functional food. Since ancient times, natural honey has been widely used as a food and conventional medicine, and has been extensively utilized for its therapeutic effects in recent years (Abdel-Latif, 2015). Besides these therapeutic effects, prebiotic activity of honey has been shown (Das *et al.*, 2015). As well as almond and honey, oat has prebiotic and health-promoting activities, especially due to its high content of β-glucan (Nwachukwu *et al.*, 2015). Tart cherry is rich in phenolic compounds, especially anthocyanins, with a strong antioxidant and anti-inflammatory activity, and thus can serve as a good source of bio-functional compounds (Dimitriou *et al.*, 2015).

In the present study, a mixture of almond, honey, Montmorency tart cherry extract and oat flour was formulated as a novel functional mixture, using the D-optimal mixture design. In order to increase the shelf life and availability of these components, and to distribute the resulting product in non-cold chain, all the components in these formulas were used in the form of powder/granule or crunchy. These mixtures could be provided for the market in small packets, cans or sachets. By adding the powder to yogurt just before consumption, consumers are given the opportunity to produce a

  

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stirred yogurt matching their taste and diet. Consumption of soluble and insoluble fibers, antioxidants and other bio-functional ingredients present in this formula can be useful for people at the risk of cardiovascular diseases, hypertension, diabetes and obesity. Functional fruit yogurts produced in this study can be served as a dessert or a snack, which can be able to provide a fraction of the daily energy, a source of daily calcium, without artificial flavors and colors, including potassium and vitamins of milk, honey, fruits, and grains.

## MATERIALS AND METHODS

### Materials

Blanched oat flakes were purchased from Golden Light Cup Co. (Tehran, Iran). Honey crunchy was donated by Nestlé Co. Ltd. (Tehran, Iran). Iranian almond was obtained from a local market. All of these materials were grounded using a domestic mill and passed through 20, 20 and 18 mesh sieves, respectively. The powder of Montmorency tart cherry extract (100% passed 80 mesh) was purchased from Bulk Powders™ (Colchester, UK). Stirred yogurt with the brand of Surmas was purchased from Pegah Dairy Co (Tehran, Iran). All chemicals were provided from Merck Chemical Co. (Darmstadt, Germany).

### Analytical Methods

### Physicochemical analysis

pH values were measured using a digital pH meter (Methrom SA, Herisan, Switzerland). Water activities ($a_w$) were measured by a water activity meter (FA-st lab, France) .The moisture and ash contents were estimated according to the standard methods of AOAC (Horwitz, 2000). Crude fiber, Neutral (NDF) and acid detergent (ADF) fibers were determined using a Tecator apparatus (Fibertec System, model 1010 Heat Extractor, Höganäs, Sweden) according to Van Soest *et al* (Van Soest *et al.*, 1991). To measure the Water Holding Capacity (WHC), 25 g of the yogurt were weighed in a centrifuge tube and centrifuged (SW14R, France) at 13500×*g* for 30 min at 10°C (Michael *et al.*, 2010). Table 1 shows the physicochemical properties and color indices of the different powders. The data are expressed as mean ± standard deviation.

**Table 1. Chemical properties and color indices of the powders**

| | pH | $a_w$ | Moisture (% | Ash (%) | Hue | Chroma | Fiber (%) | NDF* (%) | ADF** (%) |
|---|---|---|---|---|---|---|---|---|---|
| **Tart cherry** | 3.7±0.01 | 0.45±0.01 | 3.9±0.02 | 4.04±0.01 | 1.2±0.00 | 18.26±0.02 | 0.2±0.01 | 0.4±0.02 | 0.2±0.03 |
| **Honey** | 6.4±0.13 | 0.32±0.07 | 4.4±0.83 | 0.12±0.01 | -1.5±0.0 | 29.45±1.19 | 0.4±0.02 | 0. 6±0.04 | 0.2±0.02 |
| **Almond** | 6.7±0.22 | .42±0.03 | 3.4±0.26 | 2.97±0.03 | -1.5±0.0 | 21.84±0.14 | 21.2±0.04 | 36.0±0.05 | 32.0±0.01 |
| **Oat** | 6.5±0.01 | 0.47±0.05 | 8.1±0.47 | 2.1±0.44 | -1.5±0.0 | 13.21±0.34 | 1.8±0.02 | 9.6±0.01 | 0.6±0.03 |

Neutral detergent Fiber **Acid Detergent fiber

### Color Measurement

Color parameters based on CIE (Minolta, CR400, Japan) were measured as the Hue angle (h*) $h^o$ = arctan (b*/a*); Chroma ($C^* = (a^{*2}+b^{*2})^{0.5}$); and browning index (BI) (BI = 100(x- -0.31); X = (a*+1.75 l*)/(5.645l*-a*-3.012b*)).

### Texture analysis

The firmness (maximum force) and consistency (yield stress) of the initial and formulated yogurt samples were determined using a HTE Universal Testing Machine (S-Series Bench U.T.M. Model H5K-S, Hounsfield Test Equipment Ltd., UK) according to the back extrusion method (Nouri et al., 2011). Each sample was manually mixed for 2 min before analysis.

### Sensory evaluation

Sensory evaluation of the formulated yogurts was carried out by 11 trained panelists of the experts at the Agricultural Engineering Research Institute (Karaj-Iran). Evaluation was based on a 5 point hedonic scale (Moghari *et al.*, 2014).

### *Experimental Design*

Mixtures of the four ingredients (Table 2) were prepared in three blocks, according to the experimental D-optimal mixture design (Design Expert, v. 9, Stat Ease Inc., Minneapolis, USA). The proportions of almond, tart cherry extract, oat and honey ranged from zero to 80, 40, 60 and 20% w/w, respectively. Total amounts of them were 100, which were added to yogurt with the fraction of 10% w/w and mixed manually for two minutes before each analysis.

**Table 2. Generated experiments and randomized positions in the D-optimal mixture design**

| Run | Block | Almond (%) | Cherry (%) | Oat (%) | Honey (%) |
|---|---|---|---|---|---|
| **1** | 1 | 40 | 0 | 40 | 20 |
| **2** | 1 | 80 | 0 | 20 | 0 |
| **3** | 1 | 80 | 0 | 20 | 0 |
| **4** | 1 | 0 | 40 | 60 | 0 |
| **5** | 1 | 40 | 20 | 30 | 10 |
| **6** | 1 | 40 | 20 | 30 | 10 |
| **7** | 1 | 40 | 40 | 0 | 20 |
| **8** | 1 | 60 | 20 | 0 | 20 |
| **9** | 2 | 60 | 0 | 20 | 20 |
| **10** | 2 | 60 | 40 | 0 | 0 |
| **11** | 2 | 26.7 | 13.3 | 60 | 0 |
| **12** | 2 | 0 | 40 | 46.7 | 13.3 |
| **13** | 2 | 20 | 40 | 20 | 20 |
| **14** | 2 | 40 | 20 | 30 | 10 |
| **15** | 2 | 40 | 20 | 30 | 10 |
| **16** | 3 | 20 | 40 | 40 | 0 |
| **17** | 3 | 0 | 20 | 60 | 20 |
| **18** | 3 | 40 | 40 | 20 | 0 |
| **19** | 3 | 26.7 | 0 | 60 | 13.3 |
| **20** | 3 | 26.7 | 0 | 60 | 13.3 |
| **21** | 3 | 80 | 6.7 | 0 | 13.3 |
| **22** | 3 | 80 | 6.7 | 0 | 13.3 |

***Modeling and optimization of the experimental data***

Data analysis and modeling of the responses were carried out using the Stat Ease software (Design Expert, v. 9, Stat Ease Inc., Minneapolis, USA). The resulting responses were analyzed through the multiple regression analysis using the polynomial model (Cornell, 2002). Numerical and graphical analysis were used to determine optimum combinations to produce the acceptable product, with the optimum technological (maximum water holding capacity), nutritional (maximum crude fiber and minerals) and sensory (maximum palatability) attributes. All components were considered "in range".

## RESULTS AND DISCUSSION

### Physicochemical properties of the formulated yogurts

There was a significant relation between different components of the mixture and pH ($R^2$=0.9848; p<0.0002) (Table 3). Tart cherry extract was the most effective ingredient (Figure.1A). With increasing the portion of this ingredient, pH decreased from 5.15 (run 9) to 4.60 (run 17). This was in agreement with the findings of Sengul *et al.* (2012) and was probably due to the nature of acidity produced by the organic acids of tart cherry. Honey crunchy had a similar effect with a slower rate, but almond had a moderate effect. With increasing the amount of almond in the formula, pH increased. The pH of the control yogurt was 4.78±0.51. In general, these results are in accordance with the findings described by Ammar *et al.* (2015) and Varga (2006) who found out that honey had no significant effect on pH and lactic acid levels or slightly decreased the pH values of the final bio-yogurt fortified with honey, which could be attributed to fructooligosacchrides of honey.

The moisture content varied between 73.75 (run 13) and 75.94% (run 6, a central point of the mixture design), with a mean of 75.41±0.21%. The moisture content of the control yogurt was 83.33±0.51%. The effects of the ingredients on the moisture content were similar to their effects on pH (Figure.1B). All formulas had less moisture content comparing to the control, this might be due to the increase in total solids, since total solids and moisture content are inversely proportional. Rashid and Thakur (2012) also reported this phenomenon in the set yogurt prepared by the addition of honey. Moreover, Ammar *et al.* (2015) claimed that fortification of yogurt with honey increased the total solid content and the increasing rate was proportional to the honey ratios added. Changes in the moisture content may affect certain other physicochemical and textural attributes such as WHC, consistency and firmness. Ayad *et al.* (2010) found a positive relationship between hardness and total soluble solids which both increased in honey fortified yogurt. Decreasing the moisture content of the final yogurt is a way for increasing its total nutritional value.

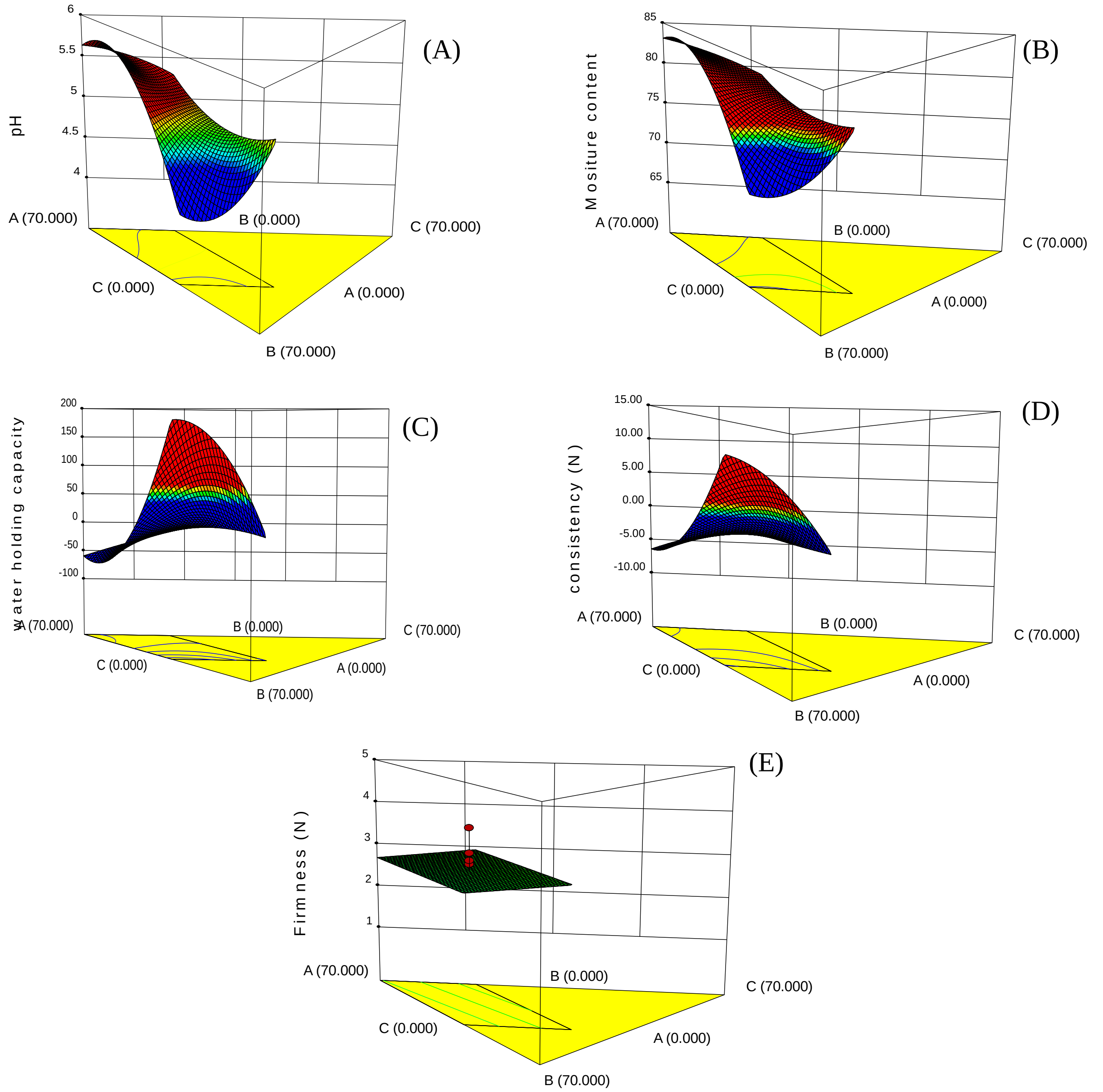


Figure 1. 3D response surface plots for pH (A); Moisture content (B); Water Holding Capacity (C); consistency (D) and Firmness (E) of formulated functional yogurts (Actual factors: A, Almond: 40%; B, tart cherry extract: 20%; C, Honey crunchy: 10% and D, oat: 30%)).

  

Tart cherry extract powder was the most effective ingredient on WHC, individually and in interaction with other ingredients. (Figure.1C). Minimum and maximum amounts of WHC were 54.02 and 82.64% in runs 9 and 17, respectively. WHC of the control yogurt was 59.30±0.94%, therefore, it can be considered that the formulation with different amounts of ingredients can improve or lessen WHC. Increasing the WHC could be due to the ability of polysaccharides of honey to bind with a significant amount of free water and osmotic activities of the other powder ingredients. Sengul *et al.* (2012) reported the concentration dependent increase of syneresis in the yogurts fortified with sour cherry. The acidity and syneresis increased in the yogurts when sour cherry was added. This could be a result of high acidity substances of sour cherry. Fruit-added yogurts are in general characterized by lower viscosity and higher syneresis. The addition of concentrated fruit decreases the water-holding capacity of proteins (Vahedi *et al.*, 2008). In addition, the difference in WHC may be attributed to the properties of different proteins present in each formula. Interactions of water with proteins are very crucial in food systems because of their effects on flavor and texture. Amino acid composition, protein conformation and surface polarity/ hydrophobicity are the most important affecting intrinsic features on the WHC of proteins (Ibrahim and Khalifa, 2015).

**Table 3. Regression coefficients and evaluation of the models for the quality responses**

| | pH | Moisture content | Water holding capacity | Consistency | Firmness | Hue | Chroma | Browning index |
|---|---|---|---|---|---|---|---|---|
| **A** | 3.46 | 58.28 | 301.91 | 16.07 | 1.99 | 3.05 | 12.11 | 63.56 |
| **B** | -13.18 | -78.41 | 2708.47 | 149.98 | 1.80 | 71.24 | 18.92 | 66.58 |
| **C** | 1.69 | 70.60 | -1203.08 | -125.03 | 3.26 | -41.28 | 0.16 | 64.35 |
| **D** | 0.46 | 37.40 | 620.82 | 33.22 | 4.33 | 8.44 | 12.08 | 64.04 |
| **AB** | 35.10 | 310.71 | -5219.85 | -298.86 | | -123.90 | -15.33 | |
| **AC** | 5.73 | 38.43 | 1527.05 | 167.73 | | 52.48 | 20.35 | |
| **AD** | 14.91 | 148.29 | -2174.78 | -131.36 | | -40.03 | 2.09 | |
| **BC** | 82.74 | 583.42 | -7856.10 | -297.75 | | -112.74 | 3.28 | |
| **BD** | 42.19 | 359.55 | -5987.74 | -334.94 | | -137.44 | -10.50 | |
| **CD** | 3.88 | -21.29 | 3354.16 | 320.45 | | 85.68 | 19.99 | |
| **ABC** | -118.69 | -851.80 | 12417.67 | 484.85 | | 117.31 | | |
| **ABD** | -59.92 | -596.61 | 10125.89 | 657.03 | | 187.74 | | |
| **ACD** | 1.03 | -2.22 | -4658.29 | 405.53 | | -102.85 | | |
| **BCD** | -106.28 | -591.28 | 5597.68 | -40.99 | | -0.25 | | |
| **p value of Model** | 0.0002 | 0.0107 | 0.002 | 0.0019 | < 0.0001 | <0.0001 | 0.0019 | < 0.0001 |
| **p value of Lack of fit** | 0.3567 | 0.6053 | 0.910 | 0.0154 | 0.2414 | 0.9913 | 0.8952 | 0.6911 |
| **mean(±SD)** | 4.85 (±0.022) | 75.42 (±0.21) | 2.05 (±1.24) | 2.44 (±0.17) | 2.80 (±0.25) | -0.5 (±0.005) | 12.33 (±0.28) | 64.36 (±0.064) |
| **$R^2$** | 0.9848 | 0.9417 | 0.7867 | 0.9683 | 0.8399 | 1.0000 | 0.8731 | 0.9862 |
| **Adj. $R^2$** | 0.9519 | 0.8153 | 0.5947 | 0.8997 | 0.8099 | 1.000 | 0.7589 | 0.9836 |
| **C.V. %** | 0.44 | 0.27 | 60.33 | 6.82 | 9.00 | 1.17 | 2.31 | 0.100 |
| **Adequate Precision** | 33.54 | 12.39 | 11.14 | 17.31 | 19.61 | 617.89 | 10.07 | 45.40 |

A: Almond, B: tart cherry extract, C: Honey crunchy, D: Oat

**Textural properties of the formulated yogurts**

The specific cubic model was adequately fitted to the response of consistency ($R^2$=0.9683; P<0.0019), with a low C.V.% (6.82) and a high adequate precision (17.307) (Table 3). Comparing the individual effects of the components in the design space (Figure.1D) demonstrated that the tart cherry extract and almond powder were the most influential ingredients. The minimum and maximum consistencies were 1.20±0.01N and 3.71±0.02N in runs 21 and 1, respectively.

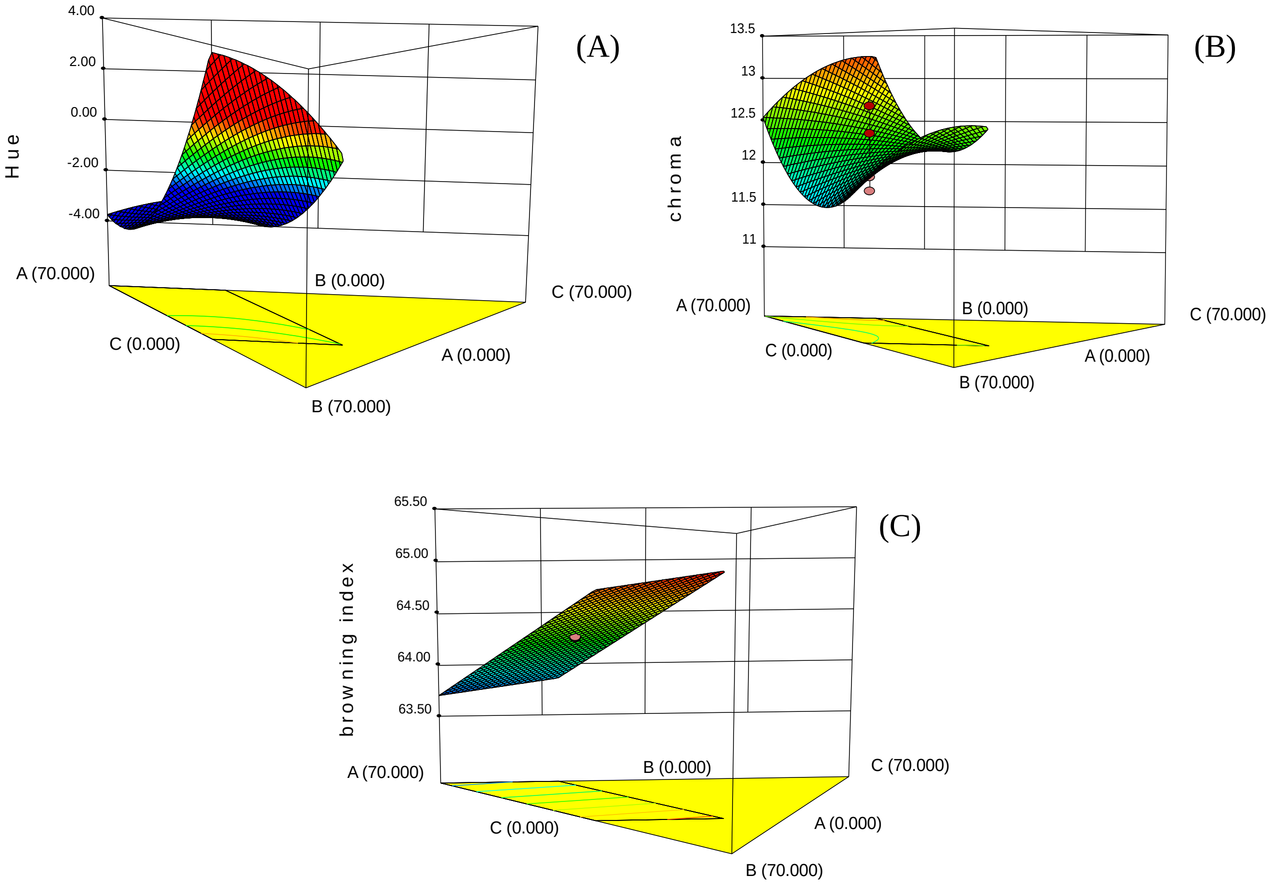


Figure 2. 3D response surface plots for color indices; Hue (A); Chroma (B) and Browning index (C) of formulated functional yogurts (Actual factors: A, Almond: 40%; B, tart cherry extract: 20%; C, Honey crunchy: 10% and D, oat: 30%)).

Consistency of the control yogurt was 1.76±0.14N with an overall mean of 2.44 ± 0.17N (Table 3). It can also be implied that the profiles of the ingredients effects on consistency and WHC (Figures. 1C and 1D) had a visually close resemblance to each other. A linear regression model ($R^2$=0.8399; P<0.0001) was the best fitted model for firmness. Almond and oat were the most effective ingredients, respectively (Figure.1E). Almond and tart cherry had similar effects. The firmness of the control yogurt was 1.95±0.12N, while the minimum and maximum firmnesses were 1.41±0.03N in run 21 and 4.23±0.01N in run 1, conforming to the consistency results. Run 1 was constituted of 40% almond, 0% tart cherry, 40% oat and 20% honey. This run had a notable higher firmness than other formulas and overall means (2.8±0.25 N, Table 3). Run 21 was constituted of 80% almond, 6.7% tart cherry, 0% oat and 13.3% honey.Figure.1E shows the opposite effects of almond and oat on firmness. Honey contains a high amount of fructose that has a high WHC and may react with many starches. Both of these attributes could result in a more rapid development of firmness (Fernández-Garía *et al.*, 1998). In contrast with our results, Ayad *et al.* (2010) declared that fortification of yogurt with honey and talbina, or with molasses and talbina decreased its hardness which could be caused by the ability of polysaccharides of honey and molasses to bind with large amounts of free water. They also found a positive correlation between hardness and total solid content which increased in honey or molasses yogurt. The firmness increase caused by the fiber has been attributed to the interactions between the dairy proteins and exogenous hydrocolloids (Fernández-Garía *et al.*, 1998). El-Nemr *et al.* (2003) also suggested that hardness was related to the dry matter of the product and slight differences in the moisture content may cause major differences in the rheological properties. Another remarkable note about this attribute, compared with other past reviewed ones, is the relatively wide range of firmness differences.

**Color Measurement**

The linear, quadratic and special cubic models were found to be the best fitted models for BI, Chroma, and hue (Table 3). The most effective factors on hue, included tart cherry and almond powder (Figure.2A). The minimum and maximum hue values were -1.56±0.00 (run 17) and +1.52±0.00 (runs 5, 6, 14, 15 which are the replications of the central point). Figure.2A showed that the factors involved in multiple interactions with each other's that could illustrate the variation in the hue values as a result of the changes in the formula. The most effective ingredients on Chroma were almond, tart cherry extract and oat, respectively (Figure.2B). Chroma was between 11.12±0.12 (run 10) and 13.36±0.04 (run 1). Run 10 was comprised of 60% almond, 40% tart-cherry, 0% honey and 0% oat and run 1 consisted of 40% almond, 0% tart cherry extract, 40% honey and 20% oat, which had the highest portion of honey and no added tart cherry.

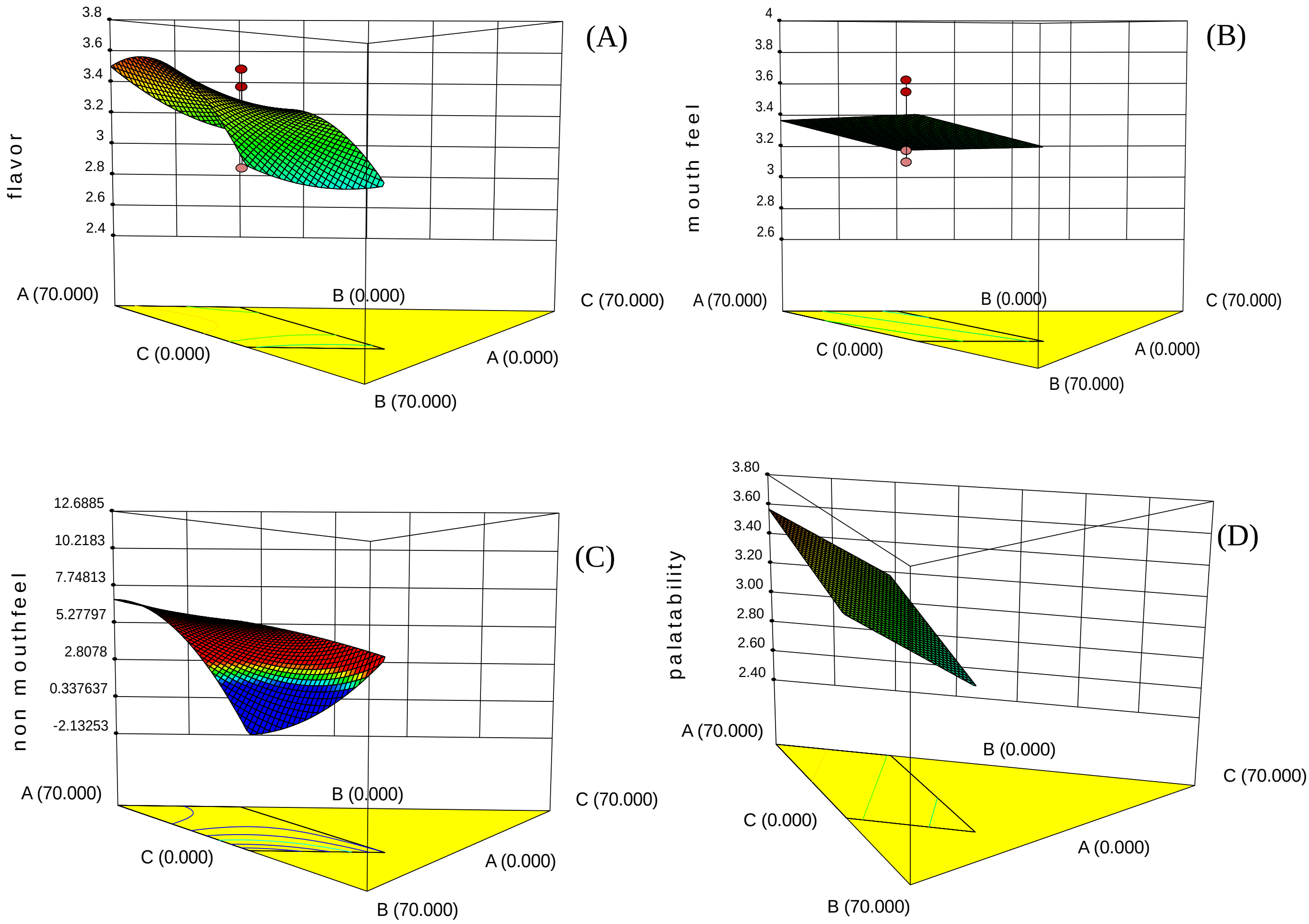


Figure 3. 3D plots showing the effects of the ingredients on the sensory evaluation of the formulated functional yogurts (Actual factors: A, Almond; B, tart cherry extract; Honey crunchy= 10% and D, oat).

  

Since the tart cherry extract, as a light pink fine powder, was a major component in the mixture design, it was expected to be the most effective ingredient on BI, but Figure.2C showed that the most effective ones were almond, honey and tart cherry, respectively. Honey, with a high amount of reducing sugars, can influence BI. A linear model was found to be the best fitted one for this index ($R^2$=0.9862; P<0.0001) (Table 3). The overall BI mean was 64.36 ± 0.064. The minimum BI value was 63.59±0.01 in runs 2 and 3, while the maximum one was 65.09±0.05 belonging to run 13. With the rise in the concentration of almond and the decrease in the concentration of tart cherry, BI was reduced significantly. In a formula with 20% almond and 40% tart cherry (10% honey and 30% oat were constant) BI was about 65. By changing this ratio to 60% almond and 0% tart cherry, BI decreased to 63.7. BI for the control yogurt was 62.99±0.03; therefore, all formulas did not have a remarkable elevated BI as compared to the control sample.

**Sensory Evaluation**

The quadratic regression model ($R^2$=0.9138; P=0.0003) was the best fitted model for the flavor of the formulated yogurts (Table 4). Almond and oat were the most effective component on this response (Figure.3A). The flavor score was between 2.57±0.5 (runs 1 and 4) and 3.64±0.6 (run 22). It seems that increasing the amount of almond and decreasing the honey concentration had a positive effect on the flavor score. Rashid and Thakur (2012) also reported less allocated scores for flavor and taste of the set yogurts containing 5 to 20 % honey. Similarly, Keating and White (1990) observed significantly lower flavor scores in the plain yogurts made with crystalline fructose; on the contrary, Varga (2006) reported that honey had the ability to decrease the solutions sourness. This property might serve to increase the consumer acceptance towards acidic products such as yogurt. Ammar *et al.* (2015) also reported that the sweet taste of honey was preferable for panelists and the flavor evaluation test of the yogurt supplemented with different honey concentrations gained the highest scores. The different results of our research can be attributed to the differences in the formulations. It seems that the sensory panelists did not prefer the taste of tart cherry and honey with high concentrations in the same formula. Although complete removal of honey did not have a desired effect.

The overall mean of the dedicated scores was 3.14 ± 0.12, indicating nearly all formulas had a satisfactory flavor. Also, it can be suggested that the sensory panel more preferred admixture formulas. The formulas with the lack of one or two components had a slightly lower score. The linear model was adequately fitted to mouth feel (Table 4; $R^2$=0.8892; P<0.0001). Almond and oat were the most effective ingredients (Figure.3B), which may be due to their particle size. The score of mouth feel texture was between 2.79±0.8 (run 17, 20) -which also had the minimum score of flavor- and 4.00±0.0 (run 10). Run 10 was constituted of 60% almond, 40% tart cherry, 0% honey crunchy and 0% oat. As can be seen, run 17 had no almond but the highest amount of honey and oat; in contrast, run 10 had no honey crunchy and oat flour. These results were not consistent with those reported by Ammar *et al.* (2015) and Riazi and Ziar (2012) who stated that high amounts (5%) of honey had a good impact on the sensory properties points allocated for color. Body-texture and taste showed that an increase in the honey content brought about an improvement in the texture, flavor and aroma of the products (P<0.05). Rashid and Thakur (2012) also reported a slightly higher score for body and texture of the yogurts fortified with honey. This difference can be attributed to the presence of other components in the formulation. The mean of the dedicated scores to mouth feel was 3.32 ± 0.1. The scores higher than 3 indicate the formula was pleasurable. Product texture can affect the sensory perception and ultimately the acceptance of a product by the consumer. Texture flavor interactions in yogurts have also been investigated by Ibrahim and Khalifa (2015).

A high coefficient of determination was reported for the relation between different formulas and non-mouth feel texture (pouring, stirring and spoonability) ($R^2$=0.9951; P<0.0001) (Table 4). This response was affected by multiple interactions. With increasing the amount of almond and decreasing the tart cherry concentration, the non-mouth feel texture score was improved (Figure.3C). This response ranged from 2.79 ±0.7 (run1) to 3.93±0.2 (run 22). The overall mean was 3.39 ± 0.042 that was in agreement with the results of consistency and WHC (Figures.1C and 1D). An association can be seen between the scores dedicated to non-mouth feel texture and consistency of the formulated yogurts in the back extrusion instrumental analysis as well as with WHC.

  

Table 4. Regression coefficients and evaluation of the models for the sensory responses

| | Flavor | Mouth feel | Non mouth feel | Palatability |
|---|---|---|---|---|
| **A** | 3.40 | 3.71 | 1.61 | 3.83 |
| **B** | -1.99 | 3.97 | -64.15 | 3.01 |
| **C** | 8.51 | 2.76 | 48.58 | 1.90 |
| **D** | 2.71 | 2.56 | -11.14 | 2.99 |
| **AB** | 6.85 | | 132.13 | |
| **AC** | -6.57 | | -64.44 | |
| **AD** | 1.45 | | 54.09 | |
| **BC** | 4.02 | | 166.65 | |
| **BD** | 8.62 | | 155 | |
| **CD** | -11.50 | | 111.34 | |
| **ABC** | | | -234.71 | |
| **ABD** | | | -268.27 | |
| **ACD** | | | 165.29 | |
| **BCD** | | | -97.80 | |
| **p value of Model** | 0.0003 | <0.0001 | <0.0001 | <0.0001 |
| **p value of Lack of fit** | 0.7730 | 0.2575 | 0.6946 | 0.7067 |
| **mean(±SD)** | 3.14(±0.12) | 3.32(±0.10) | 3.39(±0.042) | 3.22(±0.13) |
| **$R^2$** | 0.9138 | 0.8892 | 0.9951 | 0.8035 |
| **Adj. $R^2$** | 0.8362 | 0.8684 | 0.9844 | 0.7666 |
| **C.V. %** | 3.71 | 3.15 | 1.23 | 4.11 |
| **Adequate Precision** | 11.43 | 20.72 | 32.62 | 17.105 |

A: Almond, B: tart cherry extract, C: Honey crunchy, D: Oat

The linear model was realized to be the best fitted one for palatability ($R^2$= 0.8035; P< 0.0001) (Table 4). Although all components were effective, almond and honey were the most effective ones (Figure.3D). In a constant ratio of honey and oat, with increasing the amount of almond and decreasing the amount of tart cherry, the palatability score was elevated from 3.05 to 3.37 (Figure.3E). The minimum and maximum scores of palatability were 2.58±0.6 (run 17) and 3.64±0.4 (run 15, centre point). The mean of palatability was 3.22± 0.13.

**Optimization of the formulation**

The best optimum formula (desirability=0.912) consisted of 80% almond, 6.30% tart cherry extract, 6.05% honey and 7.65% oat. Besides all other nutritional and functional bioactive components, this proposed optimized powder formula would have approximately 227.39 (mg/100g) Calcium, 3.50 (mg/100g) Iron, 234.96 (mg/100g) Magnesium, 434.17 (mg/100g) Phosphorus, 2.11 (mg/100 g) Manganese and 17.13% crude fiber, 29.59% NDF and 25.67% ADF, and can be served as a good source of bio functional and prebiotic supply.

## CONCLUSION

In the present study, mixtures of almond, honey, Montmorency tart cherry extract and oat flour were formulated as powder mixtures for adding to yogurt by consumers just before consumption to produce a fresh functional flavored yogurt with desired properties. Another aim was to optimize the formulation and to find the optimum amounts of the ingredients to achieve the best final product, regarding the technological, nutritional and sensory attributes. With regards to its components, the suggested optimized powder formula can be served as a potential prebiotic mixture and a good source of nutritional and bioactive supply. This bio-yogurt can be served as a dessert or a snack, which can be able to provide a fraction of the daily energy, a source of daily calcium, without artificial flavors and colors, including potassium and vitamins of milk, honey, fruits, and grains.

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