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Use of response surface methodology to evaluate the influence of processing parameters on the quality of jelly product

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Abstract

Hawthorn berries are wild edible fruits with various health benefits. The aim of this study was to investigate the influence of two independent variable, juice extraction temperature and boiling time, on the quality of hawthorn jelly, using the response surface methodology. The experimental data were fitted to full factorial model. The colour, textural parameters and sensorial characteristics were used as attributes of quality. Both independent variables had a significant effect ($p < 0.05$) on colour, textural parameters and sensorial characteristics, but their interaction effects were generally insignificant ($p > 0.05$). The best processing parameters were boiling time of 15 min and juice extraction temperature of 50ºC, according to the desirability function which showed a value of 0,689. Principal component analysis revealed significant positive correlations ($p < 0.05$) between colour parameter luminosity and sensorial characteristics colour and general acceptability, and a negative correlation between textural parameters springiness and hardness.

Keywords: hawthorn fruits, colour, texture, sensory characteristics, optimization.

1. Introduction

Nowadays, people's interest turns to wild fruits that weren't cultivated and can be used in human nutrition. Hawthorn berries are such a fruits that can be turned into account as marmalades, jellies, beverages or sweeties [1-2].

Hawthorn belongs to Rosaceae family and it is spreader mostly in Assia, America and Europe. In Romania *Crataegus monogyna* and *Crataegus laevigata* are the species found in wild flora [3]. Hawthorn fruits are small, rounded, clustered in branches and their colour ranges from yellow to red and dark purple. The colour depends on the maturity level and it is influenced by the carotenoids and anthocyanic pigments content. According to the species, hawthorn fruits have one or many woody kernels which are not edible [4, 5].

Hawthorn was used since antiquity, mostly for medical purposes. Many studies revealed that hawthorn based products were efficient in cardiovascular diseases, such as high blood cholesterol, ventricular arrithmya, diastolic blood pressure, heart rate, coronary heart diseases. These benefic actions on the cardio-vascular system are due to the polyphenolic compounds and to the triterpene acids [6, 7]. Hawthorn was used also to improve the digestive process. It has benefits in indigestion, abdominal pain and diarrhea treatments [4]. Some important properties of hawthorn fruits are the antioxidant and free radical scavenging activity given

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by epicatechin, hypersoide and chlorogenic acid [8, 9]. Many studies regarding the chemical composition of hawthorn berries confirm the possibility to introduce these fruits in human nutrition. They are rich in proteins, fats, carbohydrates, minerals and also vitamins [3, 10]. The most important vitamins found in hawthorn fruits are vitamins C, B1, B2 and B6, as well as amino acids, sugars, sterols and organic acids [1]. High quantities of flavonoids such as hypersoide, quercitin, vitexin and procyanidins were determined in *Crataegus* species [11].

Hawthorn berries can be conserved as jelly especially because they are rich in pectin. This polysaccharide has many functions such as gelling agent and thickener. It is also useful in human nutrition, especially in digestive diseases [12].

In traditional medicine hawthorn fruits and leaves were used in Chinese and European herbal medicine. They are consumed mostly as concentrated extracts, teas and juices [4, 6]. Hawthorn berries are used both in China and Europe as foodstuff: jam, jelly, canned fruits, beverages, cider [4]. Hawthorn fruits analyzed in this study belong to the wild flora of Romania and are less known in Romanian food habits.

A suitable tool for studying the influence of various independent variables simultaneously on responses and to optimize the best conditions of process variables is the response surface methodology (RSM) [13]. Therefore, the aim of this study was to investigate the effect of two processing parameters, boiling temperature and time on quality of jelly product using RSM. The optimized parameters for desirable jelly products were also studied. The colour, textural parameters and sensorial characteristic were also investigated.

This study wants to show the possibility to conserve hawthorn fruits as jelly or marmalade, to extend their shelf-life

2.Material and Method

2.1.Material

Hawthorn fruits used in this study were collected in 2015 from Gura Humorului area, Suceava County, Romania. The wild fruits were collected after full ripening, in October. They were stored at refrigeration temperature until jelly manufacturing.

After fruits selection and washing, they were scalded with boiling water for juice extraction. Different temperatures were applied for this operation (50, 60 and 70°C). Then, the hawthorn juice extracted was boiled at 15 or 20 min at 103°C with sugar and lemon juice was added to final. The jelly was stored at room temperature until analyses were performed.

2.2. Methods

2.2.1. Colour determination. There are many systems that can describe the colour of an object. CIELab system uses the trichromatic theory which claims the fact that human eye has three colour receptors: red, green and blue and them combinations. CIELab system (Figure 1) uses three imaginary positive primaries instead of the real colours. For colour measurement a light source, an illuminant, in this case D65, and an object are needed.

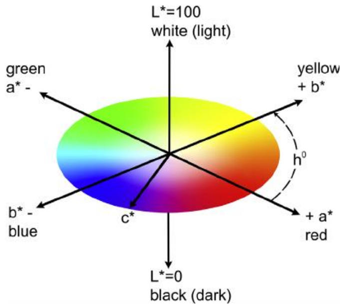


Figure 1. CIELab System [14]

The coordinate *L** is an approximate measurement of luminosity and it ranges from 0 (black) to 100 (white). *a** parameter takes values between -100 for reddish colours and +100 for the greenish ones. *b** coordinate ranges between -100 for blueness and +100 for yellowness [15, 16]. The colour of hawthorn fruits was achieved using an Ocean Optics spectrometer (USA).

2.2.2. Texture profile analysis. Texture properties of hawthorn jelly were investigated using texture profile analysis (TPA) method. The Mark-10-ESM301 Texturometer was used. Jelly samples were cubic with a side of 30 mm and were compressed twice at 10 mm distance and at 10 mm/min velocity. Texture parameters, hardness, cohesiveness, viscosity, springiness, adhesiveness, gumminess and chewiness were determined from the TPA graphic (Figure 2).

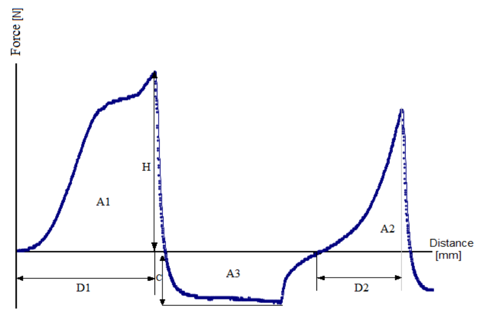


Figure 2. Load diagram in two cycles used for hawthorn jelly texture profile analysis

Hardness (H) is the maximum load applied to the sample during first compression. Cohesiveness (A_2/A_1) is calculated as the rapport between the area under the curve for the first compression (A_2) and the area under the curve for the second compression (A_1). Viscosity (C) is the height of the negative pick obtained during pressure relief. Springiness is calculated as D_2/D_1, were D_2 is the duration of contact with the sample during the first compression and D_2 is the duration during the second compression. The adhesiveness represents the area (A_3) above the curve for the decompression. Gumminess is calculated as the product between hardness and cohesiveness ($H\times A_2/A_1$). Chewiness is calculated as product of hardness, cohesiveness and springiness ($H\times A_2/A_1\times D_2/D_1$) [17, 18].

2.2.3. Sensory analysis. The jelly samples were evaluated for sensory characteristics through a preference method of nine points hedonic scale by thirty one semi-trained judges. Each attribute (aspect, colour, taste, smell, aroma, consistency, general acceptability) was evaluated according to individual preferences from score of 1 (dislike extremely), a score of 5 (neither one) to a score of 9 (like extremely) [19].

2.2.4. Statistical analysis. The influence of three levels (50, 60 and 70°C) of juice extraction temperature and two levels for boiling time (15 and 20 min) on quality of jelly made from hawthorn fruits were investigated using the RSM. The full factorial design with two independent variables was made using Stat-Ease Design Expert 7.0.0 (trial version), software which also was used to carry out analysis of variance (ANOVA) and to build the response surface, at a 95% confidence level.

The model used to predict the evolution of the quality attributed of jelly was a second order regression equation (Eq.1), which can be applied to fit the response variables:

$$Y=\beta_o+\beta_1\cdot X_1+\beta_2\cdot X_2+\beta_{11}\cdot X_1^2+\beta_{22}\cdot X_2^2+\beta_{12}\cdot X_1\cdot X_2 \quad (1)$$

where *Y* is the predicted response, β_o is a constant; β_1, β_2 – linear effects; β_{11} β_{22} and β_{12} – quadratic and interaction effects, respectively, and X_1, X_2 – the independent variables, juice extraction temperature and boiling time.

The optimization of independent variables concurrently is very important to predict the quality of jelly. The desirability function approach was used to optimize the multiple characteristics simultaneously [20].

The statistical analysis of the data obtained from colour, texture parameters and sensory sensory characteristics was performed by using Statistical Package for Social Science 24 (trial version). Principal component analysis (PCA) was applied to analyze the relationship among all response variables.

3.Results and Discussion

The best prediction model for the colour, textural parameters and sensory characteristics is 2FI model. The regression model for each of the response variables is presented in Eqs. 2-18:

$$L = -294.72 + 6.33\,X_1 + 17.74\,X_2 - 0.33\,X_1X_2 \quad (2)$$

$$a^* = -28.97+0.44\,X_1 +1.70X_2 - 0.023\,X_1X_2 \quad (3)$$

$$b^* = 81.02 - 1.37\,X_1 -3.88\,X_2 - 0.07\,X_1X_2 \quad (4)$$

$$Hardness = 64.68 -0.94\,X_1 -5.12\,X_2 - 0.09\,X_1X_2 \quad (5)$$

$$Cohesiveness = 0.93 - 8.50\,X_1 - 0.04\,X_2 + 5.80\,X_1X_2 \quad (6)$$

$$Viscosity = 12.09 - 0.22\,X_1 -0.78\,X_2 + 0.01\,X_1X_2 \quad (7)$$

$$Springiness = 4.22- 0.06\,X_1 -0.20\,X_2 + 3.95\,X_1X_2 \quad (8)$$

$$Adhesiviness = 351.35- 6.87\,X_1 -22.03\,X_2 + 0.48\,X_1X_2 \quad (9)$$

$$Gumminess = 24.85 - 0.36\,X_1 -1.89\,X_2 + 0.03\,X_1X_2 \quad (10)$$

$$Chewiness = 43.01- 0.71\,X_1 -2.92\,X_2 + 0.05\,X_1X_2 \quad (11)$$

$$Appearance = 0.82+ 0.14\,X_1 + 0.49\,X_2 - 0.01\,X_1X_2 \quad (12)$$

$$Colour = - 4.38 + 0.24\,X_1 + 0.77\,X_2 - 0.01\,X_1X_2 \quad (13)$$

$$Taste = - 2.44 + 0.18\,X_1 + 0.65\,X_2 - 0.01\,X_1X_2 \quad (14)$$

$$Smell = 2.23 + 0.08\ X_1 + 0.29\ X_2 - 5.16\ X_1 X_2 \quad (15)$$

$$Aroma = -2.20 + 0.17\ X_1 + 0.63\ X_2 - 0.01\ X_1 X_2 \quad (16)$$

$$Consistency = -10.21 + 0.31\ X_1 + 1.14\ X_2 - 0.02\ X_1 X_2 \quad (17)$$

$$General\ accept. = -3.34 + 0.20\ X_1 + 0.72\ X_2 - 0.01\ X_1 X_2 \quad (18)$$

The relative contribution of each independent variable to response variable was measured directly by the regression coefficient in the fitted model. A positive coefficient of X_1 and X_2 indicated that L^* increased with the increase of value of these variables, while the interaction between X_1 and X_2 has a negative influence on L^*. The temperature (X_1) and time (X_2) have a positive linear effect on general acceptability, while the interaction effect between them ($X_1\ X_2$) has a negative influence. A negative effect on hardness was provided by the linear and interaction regression coefficients, indicating that the increased temperature and time produced a decrease in hardness.

The response surfaces for colour (Figure 3) showed that the L^* parameter has a maximum value for the sample with 70°C juice extraction and 15 min boiling time, while a^* and b^* has maximum value at 50°C and 15 min.

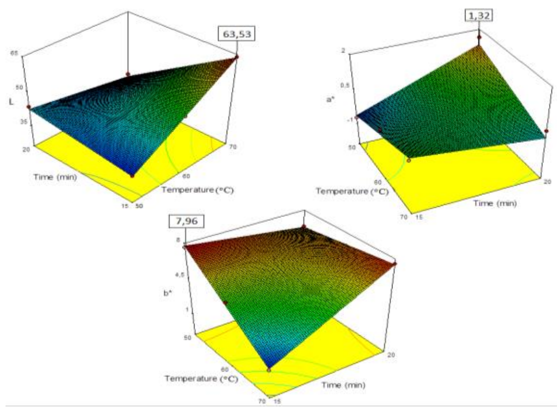


Figure 3. The evolution of colour parameters in function of juice extraction temperature and boiling time

Figure 4 shows the effect of juice extraction temperature and boiling time on the sensory characteristics.

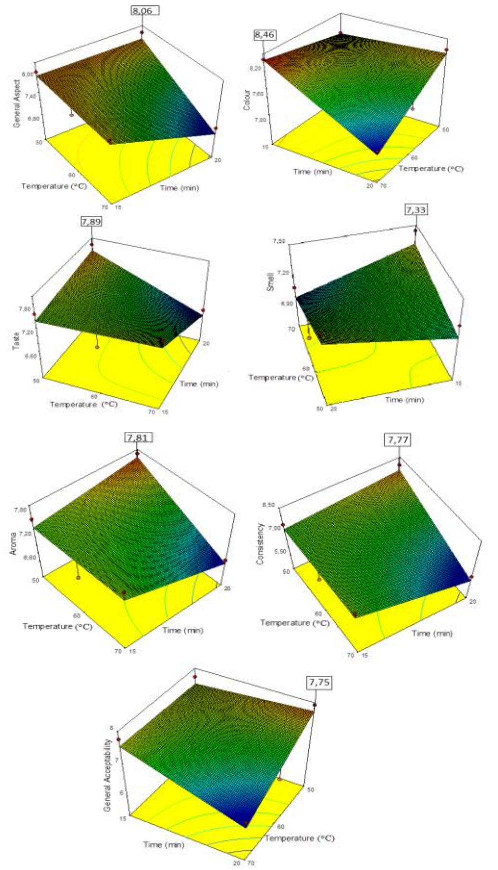
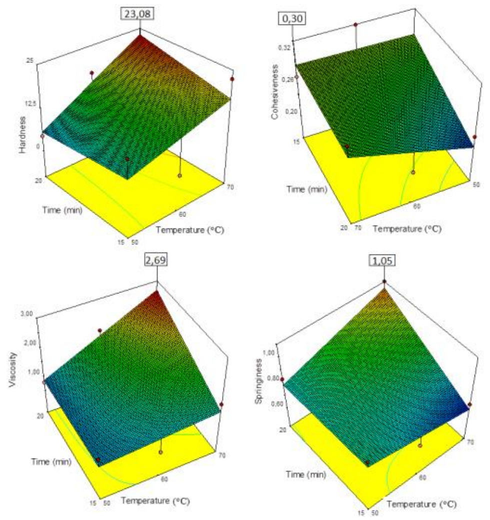


Figure 4. The evolution of sensory characteristics in function of juice extraction temperature and boiling time

The response surfaces for texture parameters are showed in (Figure 5).



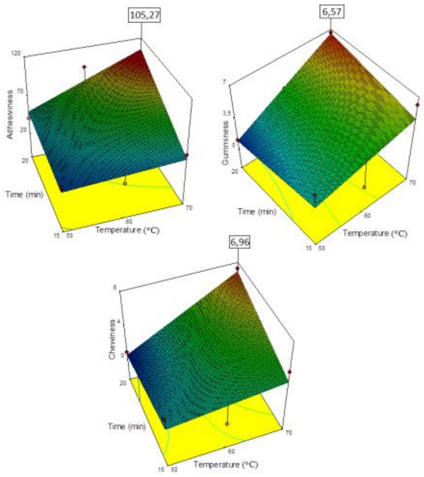


Figure 5. The evolution of texture parameters in function of juice extraction temperature and boiling time

The textural parameters hardness, viscosity, springiness, adhesiviness, gumminess and chewiness have maximum value for the sample with 50°C juice extraction and 20 min boiling time, while cohesiveness parameter has maximum value at 70°C and 15 min.

The optimization of juice extraction temperature and boiling time were made so as the *L**, *b** colour parameters, cohesiveness and chewiness and sensory characteristics (taste, aroma, consistency and general acceptability) to be maximum, while *a**, hardness, gumminess and adhesiviness were minimum. Using the methodology of desired function, it seems that juice extraction temperature of 50°C and the boiling time of 15 min, a total desirability value (D) of 0.689, are suitable for obtaining high quality jelly products (Figure 6).

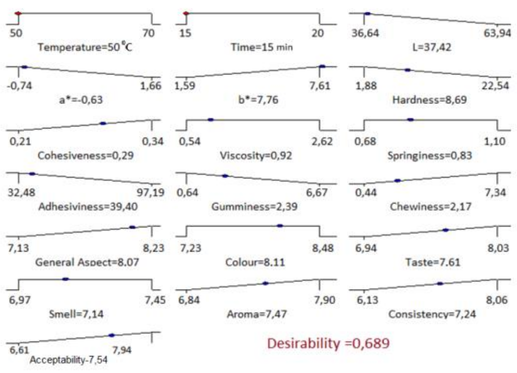


Figure 6. Desirability ramp for optimized

The principal component analysis (PCA) was used to highlight the relationship between the colour, textural parameters and sensory characteristics of jelly samples formulation. A strong correlation between the first principal component (PC 1) and the sensory characteristics was found (Figure 7). The sensorial characteristic color was well correlated with *a** parameters. Also, PC1 showed opposition between *a** and *b** colour parameters.

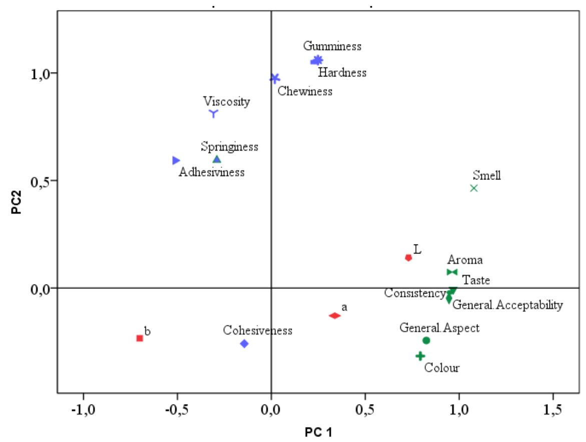


Figure 7. Principal component analysis plot the attributes of quality of hawthorn jelly

The second principal component (PC2) is correlated with the textural parameters. Along PC2 axis, good correlations were obtained for textural parameters chewiness, gumminess, and hardness.

4. Conclusion

The boiling time and juice extraction temperature processing parameters have an important influence on the quality of jelly product. The response surface methodology is a useful statistical tool able to optimize the processing parameters. The best quality of jelly in terms of colour, textural parameters and sensory characteristics were obtained for a juice extraction temperature of 50°C and a boiling time of 15 min. The two factors interaction models can be useful to predict quality of jelly product.

Compliance with Ethics Requirements. Authors declare that they respect the journal’s ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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