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CHANGES IN TEXTURE PROFILE OF AMARANTH SEEDS SUBJECTED TO SOUS VIDE TREATMENT

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Abstract: *Amaranth seeds represent an important category of pseudocereals that showed growth over time both in terms of cultivated areas and food products containing amaranth seeds. In different geographical areas, amaranth occupies an important place in terms of pseudocereal consumption, especially in Latin America and China where amaranth cultivation has been documented for over 3000 years. Due to the chemical composition in general but also due to the physical structure in particular, the cooking possibilities of amaranth seeds are limited to a certain extent. The purpose of this study was to examine and determine the impact of a new heat treatment method that can be applied to amaranth seeds in order to design and obtain new functional foods from a physical and sensory point of view. Sous-vide technology is mostly used for cooking meat or vegetables. Cereals and pseudocereals have so far not been considered suitable for sous-vide cooking due to their physical structure and low moisture content. In this study, the method adapted to these factors is described, which allows the heat treatment specific to sous-vide technology to be carried out for amaranth seeds as well. The sous vide treatment was applied at different temperature (75 °C, 80 °C and 85°C), times (60, 120, 180 and 240 min) and solid-liquid ratios (1/4, 1/5 and 1/6). The exposure time had a major influence on the textural characteristics up to the value of 180 minutes, after which the relevance of this parameter decreased.*

Keywords: amaranth, texture, sous vide

1. Introduction

The amount of intake and form of the functional food should be as it is normally expected for dietary purposes [1]. Therefore, it could not be in the form of pill or capsule just as normal food form [2]
The physicochemical properties of food are strongly influenced by the cooking process, so different parameters such as aroma, color or texture represent important characteristics in consumer preferences. Traditional heat treatments generally use high temperatures, which contributes to nutritional, flavor or color losses.
Sous-vide technology represents an alternative heat treatment model to other conventional heat treatments and an alternative to meet the growing demand for ready-to-eat foods [3]. By using sous-vide technology, we try to preserve the physical-chemical properties as close as possible to the natural state.
The use of the expression "sous-vide" has its origin in the French language and can be translated as "sub-vide" or "under vacuum". Using this expression, it is defined the process by which food is cooked at a stable temperature, in a vacuum, during a precisely set period of time [4].
Sous-vide technology can be applied to almost all food categories. They are cooked at a low temperature ranged between 50 °C and 90 °C.
A major advantage in using sous-vide technology is the high microbiological safety [5]. In addition to this fact, the use of sous-vide technology generates some improvements in terms of color and flavor

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retention, but also the reduction of the deterioration of proteins, lipids, vitamins, and other compounds that are sensitive to high temperatures [6].

Amaranth seeds have not been tested so far using sous-vide technology, however, due to their nutritional properties, there is a need to diversify food products based on amaranth seeds, especially by using new cooking techniques that can help preserving the amount of nutrients and vitamins. Amaranth is a pseudocereal known to have a high nutritional value due to amino acids, fibers, trace elements, vitamins, flavonoids, phenolic compounds and polyunsaturated fatty acid [7,8]. Antioxidants gained a considerable interest in food technology research. Their availability in various diets and their high potential role in the fight against various diseases such as cancer and neurodegenerative or cardiovascular diseases were highlighted in a variety of studies [9,10]. Amaranth seed meal is a known source of polyphenols and is recommended by doctors for use in balanced diets [11]. Polyphenols are easily degraded in the intestine of humans and animals due to the abundance of the enzyme beta-glucosidase, which releases the aglyconic fragment of the molecules [12].

The increasingly acute lack of time has irreversibly changed eating habits but also economies and technologies that have transformed the food industry into an assembly. The sous-vide technique is one of the alternatives that can satisfy the growing consumer demand for ready-to-eat foods [13].

The sous-vide technique can be applied to almost all types of food. The most eloquent example to identify the advantages of using the sous-vide technique is cooking meat for a period of 4-12 hours at temperatures of 55-80 °C. Thus, the juiciness of the meat is maintained and the flavor and texture are greatly improved [14].

Traditionally, high temperatures are used to cook food, which contributes to loss of nutritional components, flavor or color. To solve this problem, different studies were carried out to identify cooking methods that use low temperatures [15].

Using the sous-vide technique is a viable method that presents greater microbiological safety compared to conventional cooking [16]. In general, losses during traditional cooking are correlated with the degree of juiciness. By using the sou-vide technique, vitamins are preserved much better compared to cooking on the grill or in the oven, thus nutrient losses are reduced [17].

Nutrient losses are low using the sous-vide technique due to the fact that the food is cooked evenly, despite the fact that the exposure time is longer. At the same time, the use of vacuum does not allow the food to dehydrate and thus does not result in losses, as happens with cooked food.

The aim of this study was to evaluate the impact of sous-vide treatment of amaranth seed texture parameters.

2. Materials and methods

Materials

Organic amaranth seeds (*Amaranthus cruentus*) were procured from the Driedfruits warehouse (Timișoara, Romania). The seeds were authenticated according to their botanical characteristics and stored in paper bags until processing.

Souse vide technique

Different samples were analyzed, and cooked at 75 °C, 80 °C and 85 °C for 60 minutes, 120 minutes, 180 minutes and 240 minutes. For each sample cooked at different temperature and time, different ratios of amaranth seeds/water of hydration (1/4, 1/5, 1/6) were also tested, where 1 represents the amount of 10 g of amaranth seeds and 4, 5 and 6 represents the measured value of water, respectively 40 ml of hydration water, 50 ml of hydration water and 60 ml of hydration water in which the amaranth seeds were immersed and later emptied with the vessel in which they were hydrated.

Four samples were cooked by the sous-vide method at a temperature of 75 °C but using different exposure times: 60 minutes, 120 minutes, 180 minutes and 240 minutes. The following samples were cooked at 80 °C and the same exposure times. The same was done with the last four samples from the 1/4 ratio series, at a temperature of 85 °C.

For cooking with the sous-vide method, a specially designed cooking device model SIRMAN (Italy) was used (fig. 1). It is equipped with a recirculation pump, a thermostat and an electronic timer. The prepared and evacuated samples were placed in a GN1 wide opening vessel with a volume of 10 L, over which water was poured up to 2/3 of the vessel volume. The sous-vide cooking device was anchored to the edge of the vessel and was immersed with the lower part up to the mark in the water with samples. The recirculation pump with which the sous-vide cooking device is equipped helps to evenly distribute the temperature in the water in the vessel in which the samples are thermally processed. The time and temperature adjustment functions are shown on the device display and were set specifically for each sample to be analyzed.

Fig.1. Sirman sous-vide cooking device

After the programmed cooking time ended, the samples were removed from the pot of water. After cooling, the samples were removed from the glass containers, filtered and weighed. The water remaining after filtration was also measured.

The same was done with the following 12 samples that were cooked at a temperature of 80 °C and the last 12 samples at a temperature of 85 °C using different time parameters and ratio of amaranth seeds/hydration water, depending on each sample.

Texture analysis

The texture profile evaluation test was performed using a TVT 6700 texturometer (Perten Instruments, Stockholm, Sweden). A compression cylinder with a diameter of 35 mm was attached to this device. It was used to press with a determined force on the analyzed samples from all samples. For the analysis of the samples, they were dimensioned to a diameter of 30 mm and a height of 10 mm. The principle of the method is defined by the application of a force on samples of amaranth seeds cooked using sous-vide technology, in the preparation of which different and specific parameters of time, temperature and amaranth seed/hydration water ratio were used, inside the vessel in which the sample was made and which was subsequently emptied.

The compression of the samples was carried out on the surface of a press table. Using the software, the device was programmed to apply a compressive force to the sample twice. Thus, the first compression was performed at a displacement equal to 75% of the sample height, applying a speed of 2 mm/s, after which the piston returned to the initial position. The second compression was performed at a cylinder displacement equal to 75% of the sample height, while also maintaining the compression speed.

By using this method, the device records in real time the resistance force against the analyzed sample and at the same time records the calculated parameters. The result consists in recording the values of the forces, but also the displacements and the calculation of the texture parameters derived from the integration of the two recorded values.

Experimental Design and Statistical Analysis

The three-level Box–Behnken design was adapted in this study to investigate and optimize the effect of the independent variables of temperature (X_1), time (X_2), and solid-liquid ratio (RSL) (X_3) on hardness and adhesiveness. The coded levels of the variables are -1, 0 and 1 were 75 °C/120 min/ 1/6, 80 °C/180 min/ 1/5 and 85 °C/180 min/ ¼, respectively. All calculations and graphics were carried out using the statistical software Design Expert 11 (trial version, Minneapolis, MN, USA). Triplicate experiments were conducted in order to validate the optimal extraction conditions.

The Box–Behnken design was based on a second-order (quadratic) polynomial response surface model using the following equation:

$$y = b_0 + \sum_{i=1}^{n}(b_i x_i) + \sum_{i=1}^{n}(b_{ii} x_{ii}^2) + \sum_{ij=1}^{n}(b_{ij} x_i x_j) (1)$$

where y is the predicted response (hardness and adhesiveness), x_i stands for the coded levels of the design variable (temperature (X_1), time (X_2), and solid-liquid ratio (RSL) (X_3)), b_0 is a constant, b_i is the linear effects, b_{ii} is the quadratic effects and b_{ij} is the interaction effects.

3. Results and discussion

3.1. Texture parameters evolution during the sours-vide treatment

The evolution of the texture parameters is presented in fig. 2. The texture parameters studied (hardness and adhesiveness) were determined automatically from the displacement of the material (hardness represents the resisting force opposed by the sample after it was compressed; adhesiveness represents the resistance recorded when the piston detaches from the analyzed sample after the first compression. This parameter is calculated by integrating the negative area under the curve).

Based on the results obtained from the determinations made major differences were found between the influences of the parameters studied on amaranth seed texture. These differences are directly influenced by the parameters used in each individual sample. The exposure time and the temperature at which the amaranth seeds were cooked had a decisive role in identifying the best option for obtaining a food product with optimal textural parameters.

Temperature is an important parameter in modifying adhesiveness, while in hardness modifications the same temperature parameter (85 °C) makes the difference in achieving an optimal texture.

According to the graphs, an increase in the adhesiveness can be observed at temperatures of 75 °C and 80 °C, while at the temperature of 85 °C the adhesiveness decreases steadily. The hardness was directly influenced by the exposure time where, according to the graphs, the time of 240 minutes represents the point of convergence of the values that form a common point, less in the case of the temperature of 85 °C and amaranth seed/water ratio for hydration 1/6 where the measured value was the lowest.

The ratio of amaranth seeds/water for hydration is an important parameter due to the fact that during the sous-vide heat treatment process the starch in the composition of amaranth seeds gels. Thus, the greater the amount of water, the more the starch granules have the opportunity to change their structure, a fact that directly leads to changes in texture.

The exposure time had a major influence on the textural characteristics up to the value of 180 minutes, after which the relevance of this parameter for texture parameters decreased.

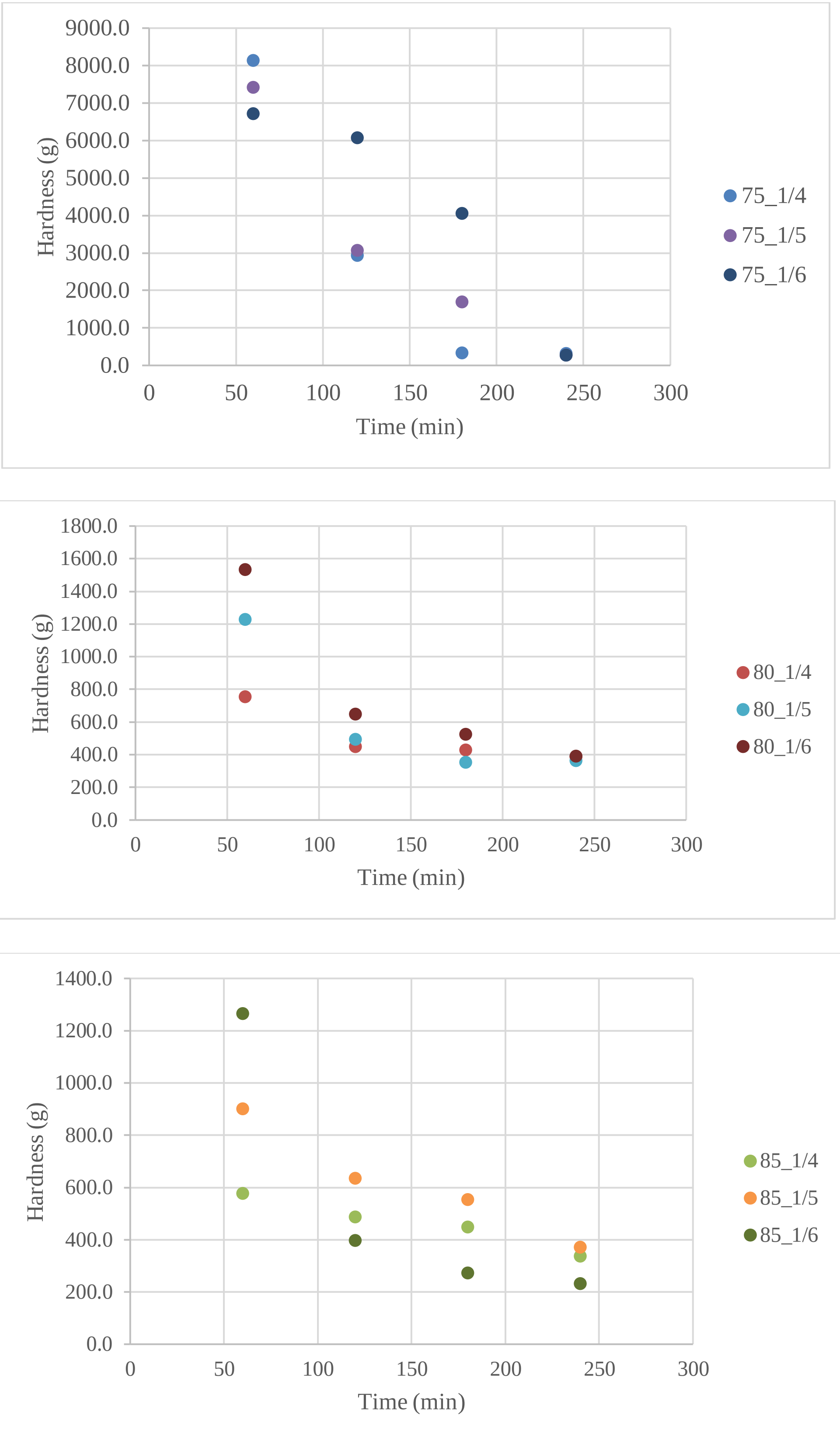

Fig. 2. Changes in hardness over time, depending on temperature parameters and amaranth seed/water ratio used for hydration

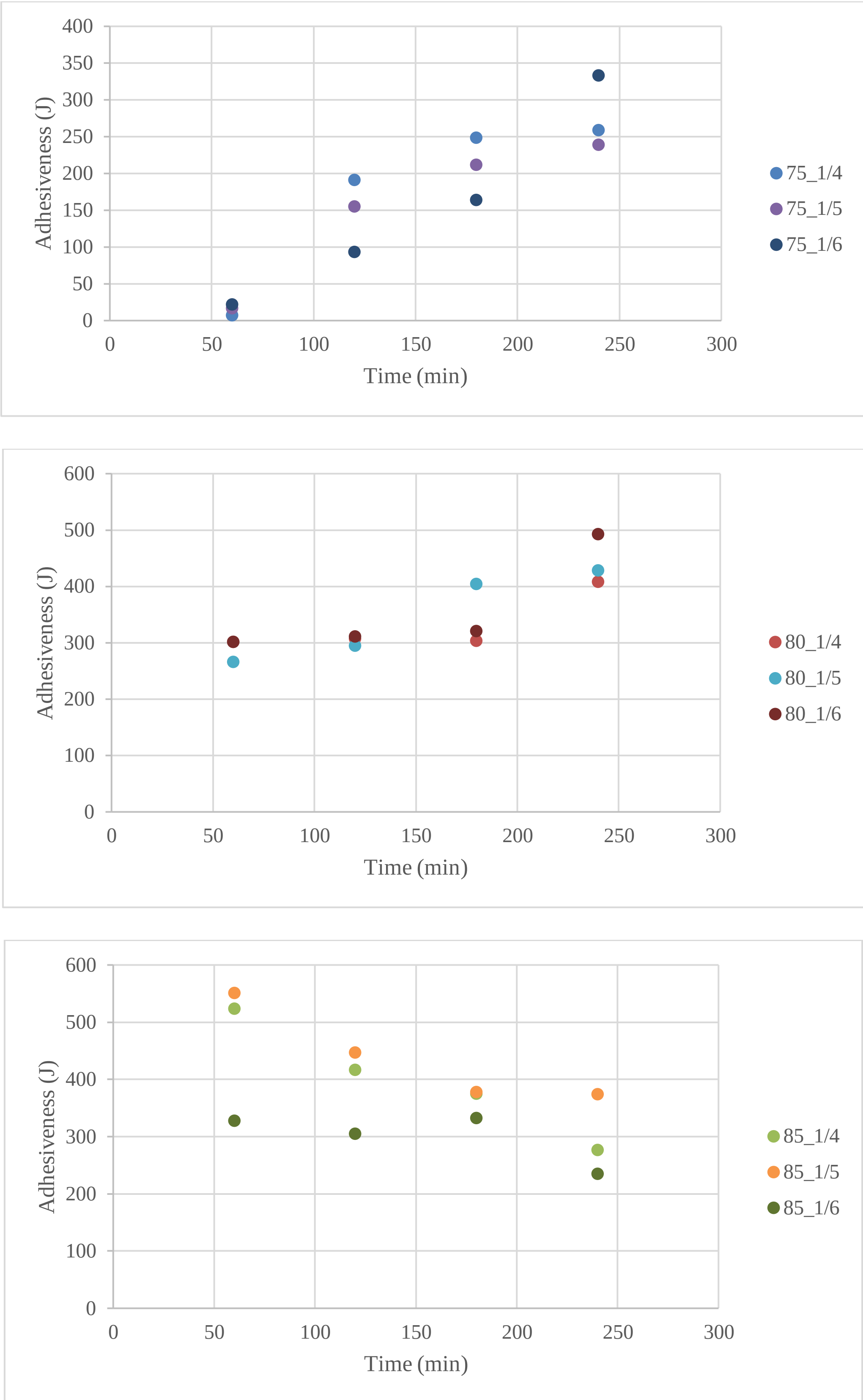

Fig. 3. Adhesiveness changes depending on temperature parameters and amaranth seeds/water ratio used for hydration

3.2. Box-Behnken design and model fitting

Box-Behnken design was applied to study the combined effects of the three parameters (temperature, time and RSL) on amaranth texture parameters (hardness and adhesiveness) during the sous-vide treatment. The regression coefficients of the two proposed model are presented in Table 1; the two models were significant ones (*p<0.0001*), and the F-value was 10.34 for hardness and 9.4 for adhesiveness, respectively. The model developed for hardness and adhesiveness are significant in terms of ANOVA and the regression of the two models are higher than 0.80. The parameters (temperature, time and RSL) presented significant linear effects of hardness and adhesiveness.

The interaction effects between temperature and time, and time and RSL were significant for hardness and adhesiveness. The quadratic effects were not significant for the two parameters.

3.3. Fitting of second order polynomial equations

The relationship between the texture parameters and the sous-vide technique were assessed using a second order polynomial equations using the Box Behnken design. The equations which describe the correlation between the input and outputs are presented below:

$$Hardness = 259.1 - 713.6 \cdot X_1 - 744.4 \cdot X_2 - 309.2 \cdot X_3 + 676.1 \cdot X_1 \cdot X_2 + 807.6 \cdot X_1 \cdot X_3 + 184 \cdot X_2 \cdot X_3 + 861.1 \cdot X_1^2 + 88.0 \cdot X_2^2 + 230.4 \cdot X_3^2 \quad (2)$$

$$Adhesiveness = 398.6 + 67.2 \cdot X_1 + 43.0 \cdot X_2 - 2.8 \cdot X_3 - 53.3 \cdot X_1 \cdot X_2 + 4.4 \cdot X_1 \cdot X_3 - 6.1 \cdot X_2 \cdot X_3 - 98.0 \cdot X_1^2 - 9.8 \cdot X_2^2 - 42.1 \cdot X_3^2 \quad (3)$$

Table 1.

Analysis of variance for hardness and adhesiveness modelling using Box Benhken design

	Hardness					Adhesiveness				
Source	Sum of squares	Df	Mean Square	F-value	p-value	Sum of squares	Df	Mean Square	F-value	p-value
Model	4.3E+7	9	4.8E+6	10.4	< 0.0001	2.1E+5	9	23668.8	9.4	< 0.0001
A-temperature	1.3E+7	1	1.3E+7	28.2	< 0.0001	85990.0	1	85990.0	34.1	< 0.0001
B-time	8.3E+6	1	8.3E+6	17.9	0.0004	15356.6	1	15356.6	6.1	0.0232
C-RSL	2.5E+6	1	2.5E+6	5.4	0.0310	2183.4	1	2183.4	0.87	0.3633
AB	4.3E+6	1	4.3E+6	9.3	0.0064	50170.5	1	50170.5	19.9	0.0003
AC	8585.7	1	8585.7	0.02	0.8932	12.3	1	12.3	4.9E-3	0.9448
BC	9.4E+6	1	9.4E+6	20.3	0.0002	37881.7	1	37881.7	15.0	0.0010
A^2	0.000	0				0.000	0			
B^2	9.4E+5	1	9.4E+5	2.1	0.1691	8698.6	1	8698.6	3.46	0.0786
C^2	0.000	0				0.000	0			
Residual	8.8E+6	19	4.6E+5			47819.9	19	2516.8		
Lack of Fit	8.8E+6	17	5.1E+5			47819.9	17	2812.9		
Pure Error	0.000	2	0.000			0.000	2	0.000		
Cor Total	5.2E+7	28				2.6E+5	28			
Model Stdev	680.98					50.17				
Model R^2	0.8318					0.8167				

3.4. Surface response 3D plots

In figure 4, 5 are presented the evolution of hardness and adhesiveness in function of temperature, time and RSL. In the case of combined influence of temperature and tine on hardness, it can be observed that at high temperature and times the hardness reaches the lowest values. In the case of the combined influence of temperature and RSL, the hardness reached the low values at high temperature and RSL. The time and RSL influences negatively the hardness.

In the case of combined influence of temperature and time on adhesiveness, it can be observed that at the maximum time applied and medium temperature, the adhesiveness reached the high values, while at the lowest times the hardness reached the lowest values. In the case of the combined influence of temperature and RSL, the adhesiveness reached the low values at low temperature irrespective of the RSL applied.

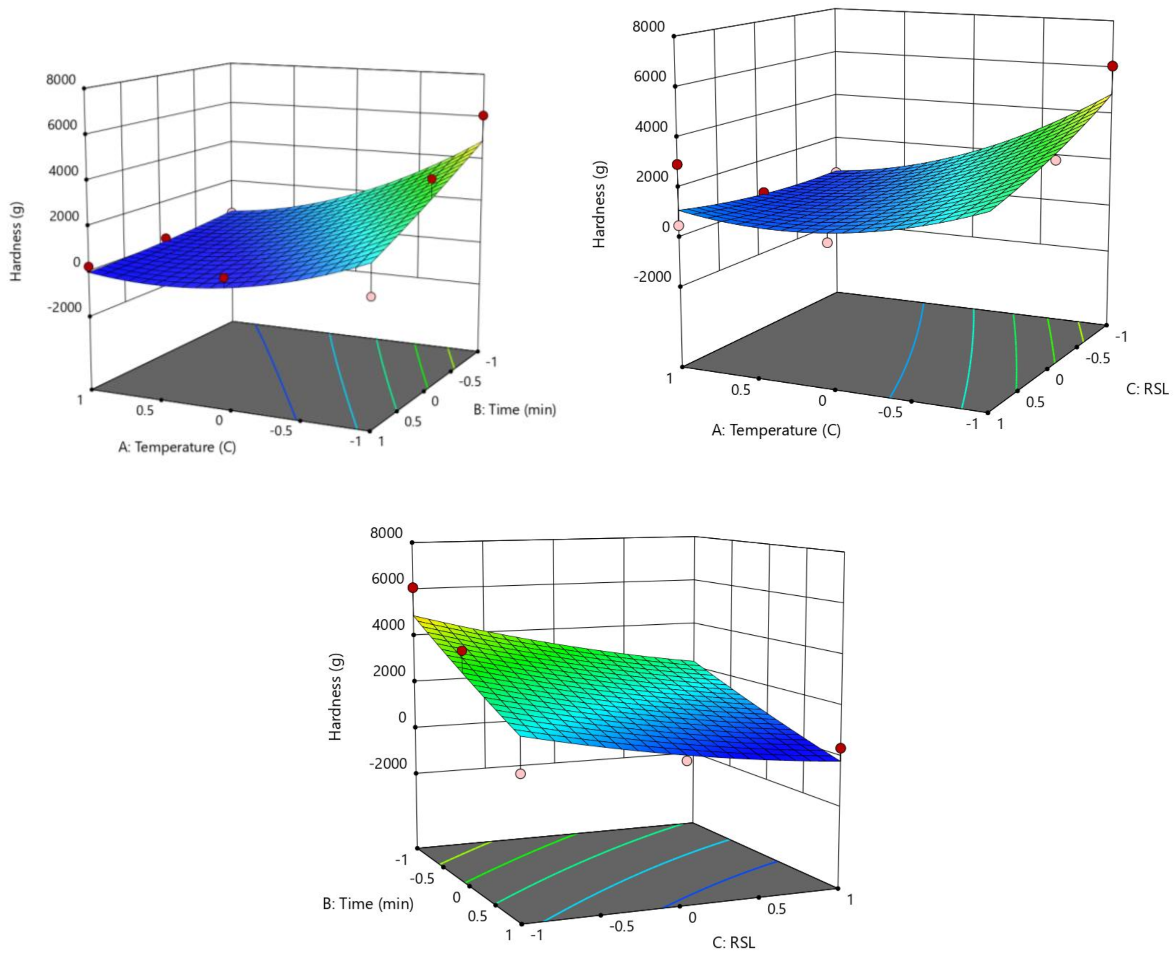

Fig. 4. 3D evolution of hardness of amaranth seed submitted to sous-vide treatment

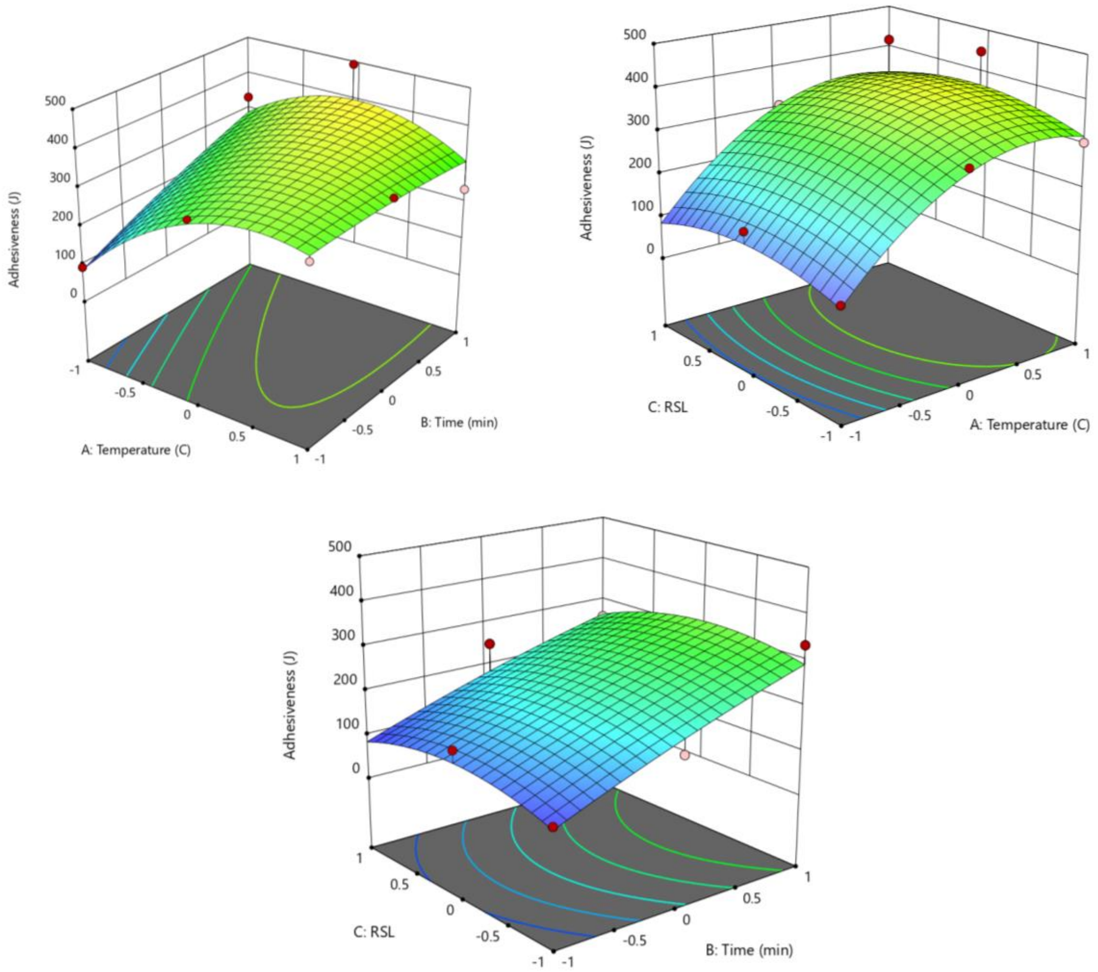

Fig. 5. 3D evolution of adhesiveness of amaranth seed submitted to sous-vide treatment

4. Conclusion

Considering the results obtained from the determinations differences were found in terms of the influence of the parameters studied on amaranth seed texture. These differences were directly influenced by the parameters used in each individual sample. The exposure time and the temperature at which the amaranth seeds were cooked had a decisive role in identifying the best option for obtaining a food product with optimal textural parameters. The hardness was directly influenced by the exposure time where, according to the graphs, the time of 240 minutes represents the point of convergence of the values that form a common point, less in the case of the temperature of 85 °C and amaranth seed/water ratio for hydration 1/6, where the measured value was the lowest. Box-Behnken design was applied to study the combined effects of the three parameters (temperature, time and RSL) on amaranth texture parameters (hardness and adhesiveness) during the sous-vide treatment. The regression coefficients of the two proposed models were significant ones (*p<0.0001*), and the F-value was 10.34 for hardness and 9.4 for adhesiveness, respectively. The free parameters (temperature, time and RSL) presented significant linear effects of hardness and adhesiveness.

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