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APPLE PUREE AS SUCROSE REPLACER IN INCREASING THE NUTRITIONAL VALUE AND DECREASING THE ENERGY VALUE OF THE PASTRY PRODUCTS

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Abstract: *In recent decades, people's interest in adopting a healthy lifestyle, characterized by low sugar consumption, has seen a significant increase. This change in attitude comes in response to the many scientific studies that highlight the negative impact of excessive sugar consumption on human health. Aspects such as the alarming increase in the rate of obesity, type II diabetes and other metabolic conditions have prompted more and more people to reevaluate and adjust the nutritional content of their diet. Substituting sugar (with apple puree, oligofructose, stevia, inulin) in pastry products is a healthy alternative, but this alternative can change the properties of the pastry products. Using the response surface methodology, in order to obtain optimal textural and physical properties of the muffins, the values of the following parameters have been established: the substitution of sugar in a percentage of 42.78-43.39%, baking temperature between 183.83 and 183.99 °C; baking time between 14.66 and 13.80 min. The sensory analysis of the muffins obtained under the mentioned conditions demonstrated that there are no significant differences regarding the acceptability between the muffins with sucrose and with apple puree used as replacer. Moreover, apple puree muffins have a high nutritional value and a lower energy value by replacing a significant percentage of sugar.*

Keywords: *apple puree, muffins, sensory evaluation, sugar, physical properties, texture*

1. Introduction

The continued increase in obesity and type II diabetes is frequently associated with the consumption of high-sucrose products. That is why, lately, consumers have been more and more oriented towards foods with a low calorie content. Obtaining pastries and bakery products with low energy value is easy to achieve, but, the obtained products may present unsatisfactory/unacceptable organoleptic properties for consumers. Due to the multiple roles of sucrose in the process of obtaining pastry products (provides sweetness, controls moisture retention, influences air incorporation, and improves texture), the substitution of sugar represents a challenge for manufacturers in the food industry [1]. That is why it is important to find substitutes for sugar, which maintain the same quality of pastry and bakery products. Some examples could be: apple puree, date syrup, *Nypa fruticans* syrup, inulin, grape syrup, Stevia, oligofructose, and apple pomace [1–15].

Muffins, along with sponge cake, pound cake and croissant, are pastry products highly appreciated by consumers due to their special sensory properties: appearance, smell, taste, texture, color. The disadvantage of these products is represented by the high energy value given by the high sucrose content [16]. Due to the high glycemic index of these products (given by sucrose), diabetics are warned against consuming muffins. Therefore, replacing sucrose with substitutes whose caloric content is lower than of sucrose is a healthy alternative that

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comes to the aid of diabetics and those interested in adopting a healthy lifestyle. This change in attitude comes in response to the many scientific studies that highlight the negative impact of excessive sugar consumption on human health [17].

Apple puree is an ingenious substitute in pastry products, bringing extra flavor and texture [15]. Apple puree is a healthy alternative to refined sugar, adding sweetness and moisture to baked goods without compromising taste. This substitute not only enriches the flavor, but also contributes to increasing the nutritional value of the products, providing bioactive compounds, fibers, essential vitamins and minerals [14].

Due to its high content of soluble fibers, such as pectin, apple puree does not only improve the taste, but it also brings significant nutritional benefits [18,19].

An important aspect in using apple puree as a substitute in baked goods is its ability to influence texture and physical properties. Pectin, a component of apple puree, acts as a thickening agent and stabilizer of the products' structure, giving them a softer and more uniform consistency [19–21]. This aspect is supported by the interactions between pectin and other dough ingredients, demonstrating the ability of apple puree to improve the quality of pastry products.

This manuscript focuses on the effect of replacing sugar in muffins with apple puree in different percentages. Thus, in this study, physical and textural properties, color parameters, and sensory characteristics of muffins obtained by replacing sugar with apple puree, were investigated. The objective was to evaluate the effect of three independent variables: percentage of sugar substituted with apple puree, baking time and temperature, using the Response Surface Methodology (RSM) program.

2. Material and methods

2.1. Materials

Cooked apple puree was obtained according to the method described by Huțu and Amariei [25].Seventeen muffin batters with different contents of apple puree were prepared according to samples generated by Design Expert v11 (trial version, Stat-Ease, Minneapolis, Minnesota, MN, USA). Wheat flour, white sugar, baking powder, iodized table salt, milk, sunflower oil, and fresh eggs were purchased from a local supermarket.

2.2. Muffins batter preparation

The eggs and sugar/apple puree were stirred for 240 s at maximum speed then the milk and oil were added in KitchenAid - Professional Mixer (KPM5, KitchenAid, St. Joseph, MI). The obtained mixture was stirred for 60 s at minimum speed, then the solid ingredients were added. Next, the mixture was stirred for 60 s at minimum speed and then stored at refrigeration temperature for 1 h.

2.3. Texture profile analysis (TPA)

Texture profile analysis was performed using a Perten TVT-6700 texturometer (Perten Instruments, Stockholm, Sweden) by compressing the sample using a 25 mm diameter stainless steel cylindrical probe. The trigger force was selected with the mass of 5 g and the test speed was 1 mm/s with a deformation of 25% of the initial height and an interval of 5 s between compression cycles. TPA from which the three textural parameters were obtained: hardness, chewiness, and cohesiveness [25]. All measurements were performed in triplicate.

2.4. Muffin height

The height of the muffins was determined at room temperature using a digital caliper l caliper (Mitutoyo Deutschland GmbH, Neuss, Germany) [16,27]. The measurement was taken from the highest point to the bottom of the muffin [27]. All measurements were performed in triplicate.

2.5. Volume of muffins

The volume of the muffins was determined at room temperature by the rapeseed displacement according to the AACC (2000) method 10-05 [28–31]. All measurements were performed in triplicate.

2.6. Weight loos during baking

Baking loss (WL) was determined according to the method described by Simona Grasso et al. [23]; the mass of the dough (W_b) was determined for each sample and the mass of the muffins (W_m) obtained after baking using the analytical balance Partner AS 220.RS (Radwag, Torunska, Poland), and the calculation formula used was Equation 1 [16,22,23,31,32]. All measurements were performed in triplicate.

$$WL(100\%) = ((W\_b - W\_m)) / W\_b \times 100 \quad (1)$$

2.7. Sensory analysis

A number of 17 samples suggested as representative by the Experiment Programming were analyzed from a sensorial point of view. The analyzed characteristics were: appearance, smell, taste, color, texture, and acceptability. A nine-point hedonic scale was used for the sensory analysis (9 = I like it extremely much; 8 = I like it very much; 7 = I like it moderately; 6 = I like it slightly; 5 = I neither like it nor dislike; 4 = I like it moderately; 2 = I dislike it a lot; 1 = I dislike it very much) [33–35]. The sensory analysis was carried out by 60 panelists.

2.8. Experimental design

The effect of the independent variables (apple puree percentage (APP), baking time (t), baking temperature (T)) on hardness, chewiness, cohesiveness, muffin height, volume, and baking loss, were monitored using the Box-Behnken Response Surface Experimental Design. The establishment of experimental matrices was performed using Design Expert v11 (trial version, Stat-Ease, Minneapolis, Minnesota, MN, USA), and the Response Surface Methodology (RMS) was used for modeling.

In order to study the effects of the 3 independent variables on the muffins, the central compositional experiment was used, taking into account three factors: the percentage of apple puree, varied from a minimum of 0 to a maximum of 100%; the baking time, varied from a minimum of 13 to a maximum of 15 min and the baking temperature from a minimum of 180 to a maximum of 220 °C [22–24].

The coded levels of the design variables are shown in Table 1, and the coded values and the actual values of the factors used in programming the experiment regarding the influence of the percentage of apple puree, of baking time and baking temperature on the textural and physical properties of the muffins are shown in Table 2.

Following the establishment of the experimental matrix, the Box-Behnken experimental model, which presents 3 factors and 3 levels, included 17 experiments, out of which 5 were in the central point.

3. Results and discussion

3.1. Texture profile analysis (TPA)

The quadratic (second-order) polynomial model was used to represent the evolution of muffin hardness, chewiness and cohesiveness. The model was chosen based on low p-value ($p < 0.05$), favorable Lack of Fit (non-significant) and higher coefficient of determination (R^2).

Table 1.
Levels of the independent variables in the Box-Behnken experimental model regarding the influence of the percentage of apple puree, of baking time and baking temperature on the muffin properties

Variable	**-1**	**0**	**1**
Apple puree percentage (%)	0	50	100
Baking time (min)	13	14	15
Baking temperature (°C)	180	200	220

Table 2.
The coded values and the actual values of the factors used in programming the experiment regarding the influence of the percentage of apple puree, baking time and baking temperature on the properties of the muffins

Run	**Coded values**			**Actual values**		
	APP	**t**	**T**	**APP (%)**	**t (min)**	**T (°C)**
1	-1	-1	0	0	13	200
2	1	-1	0	100	13	200
3	-1	1	0	0	15	200
4	1	1	0	100	15	200
5	-1	0	-1	0	14	180
6	1	0	-1	100	14	180
7	-1	0	1	0	14	220
8	1	0	1	100	14	220
9	0	-1	-1	50	13	180
10	0	1	-1	50	15	180
11	0	-1	1	50	13	220
12	0	1	1	50	15	220
13	0	0	0	50	14	200
14	0	0	0	50	14	200
15	0	0	0	50	14	200
16	0	0	0	50	14	200
17	0	0	0	50	14	200

APP – apple puree percent, *t* – baking time, *T* – baking temperature.

The quadratic model was determined to be statistically significant by analysis of variance (ANOVA). The Box-Behnken model with experimental and predicted values for muffin hardness, chewiness and cohesiveness are presented in Table 3, and the results of the analysis of variance (Table 4) demonstrate that the chosen model explains and predicts most of the variation in hardness (R^2 = 0.992), chewiness (R^2 = 0.897), and cohesiveness (R^2 = 0.973).

Equations 2, 3, 4 describe the effects of apple puree percentage (*APP*), baking time (*t*) and baking temperature (*T*) on muffin hardness, chewiness and cohesiveness.

Table 3.
Box-Behnken model with experimental and predicted values for muffin hardness, chewiness and cohesiveness

Run	Independent Variables			Measured Response			Predicted Response		
	APP (%)	t (min)	T (°C)	Hardness (N)	Chewiness (N)	Cohesiveness (nd)	Hardness (N)	Chewiness (N)	Cohesiveness (nd)
1	0	13	200	9.99	5.96	0.61	9.99	6.06	0.62
2	100	13	200	8.31	6.71	0.75	8.28	6.55	0.75
3	0	15	200	9.15	5.35	0.64	9.16	5.51	0.63
4	100	15	200	9.22	6.98	0.74	8.99	6.89	0.73
5	0	14	180	9.27	5.55	0.61	9.25	5.40	0.61
6	100	14	180	8.88	5.31	0.81	8.87	5.39	0.82
7	0	14	220	9.51	5.31	0.69	9.50	5.24	0.68
8	100	14	220	7.98	6.95	0.71	7.99	7.11	0.70
9	50	13	180	9.35	6.75	0.68	9.63	6.83	0.67
10	50	15	180	9.41	6.24	0.68	9.41	6.25	0.68
11	50	13	220	9.17	7.15	0.66	9.16	7.14	0.66
12	50	15	220	9.02	7.57	0.64	8.98	7.50	0.65
13	50	14	200	9.15	6.03	0.64	9.17	5.86	0.64
14	50	14	200	9.21	5.33	0.63	9.17	5.86	0.64
15	50	14	200	9.18	5.46	0.65	9.17	5.86	0.64
16	50	14	200	9.22	6.29	0.63	9.17	5.86	0.64
17	50	14	200	9.13	6.18	0.66	9.17	5.86	0.64

APP – apple puree percent, *t* – baking time, *T* – baking temperature.

$$\begin{aligned}\mathrm{Hardness\ (N)} = {} & 917.4 - 46.875 \times \mathrm{APP} - 3.125 \times \mathrm{t} - 15.75 \times \mathrm{T} + 38.5 \times \mathrm{APP} \times \mathrm{t} \\ & - 28.25 \times \mathrm{APP} \times \mathrm{T} - 5.75 \times \mathrm{t} \times \mathrm{T} - 19.45 \times \mathrm{APP}^2 + 13.05 \times \mathrm{t}^2 \\ & - 7.2 \times \mathrm{T}^2 \end{aligned} \tag{2}$$

$$\begin{aligned}\mathrm{Chewiness\ (N)} & \\ = {} & 586.19 + 46.8409 \times \mathrm{APP} - 5.29125 \times \mathrm{t} + 39.0881 \times \mathrm{T} \\ & + 22.2567 \times \mathrm{APP} \times \mathrm{t} + 47.0015 \times \mathrm{APP} \times \mathrm{T} + 23.3992 \times \mathrm{t} \times \mathrm{T} \\ & - 37.7725 \times \mathrm{APP}^2 + 76.8218 \times \mathrm{t}^2 + 30.0831 \times \mathrm{T}^2 \end{aligned} \tag{3}$$

$$\begin{aligned}\mathrm{Cohesiveness} = {} & 0.6468 + 0.0575 \times \mathrm{APP} - 0.001875 \times \mathrm{t} - 0.011375 \times \mathrm{T} \\ & - 0.00875 \times \mathrm{APP} \times \mathrm{t} - 0.04475 \times \mathrm{APP} \times \mathrm{T} - 0.00456 \times \mathrm{t} \times \mathrm{T} \\ & + 0.04085 \times \mathrm{APP}^2 + 0.0016 \times \mathrm{t}^2 + 0.0201 \times \mathrm{T}^2 \end{aligned} \tag{4}$$

Table 4.
Analysis of variance (ANOVA) for the polynomial model in terms of muffin hardness, chewiness and cohesiveness

Hardness (N)					
Source	**Sum of Squares**	**df**	**Mean Square**	***F*-value**	***p*-value**
Model	3.11	9	0.3450	109.25	<0.0001
APP	1.56	1	1.56	493.25	<0.0001
t	0.0000	1	0.0000	0.0158	0.9034
T	0.1891	1	0.1891	59.89	0.0001
APP × t	0.7656	1	0.7656	242.45	<0.0001
APP × T	0.3249	1	0.3249	102.89	<0.0001
t × T	0.0110	1	0.0110	3.49	0.1039
APP^2	0.1203	1	0.1203	38.08	0.0005
t^2	0.1058	1	0.1058	33.50	0.0007
T^2	0.0413	1	0.0413	13.07	0.0086
R^2	0.992				
Chewiness (N)					
Model	7.74	9	0.8600	6.70	<0.0001
APP	1.79	1	1.79	13.91	0.0074
t	0.0231	1	0.0231	0.1801	0.6841
T	1.22	1	1.22	9.54	0.0176
APP × t	0.1936	1	0.1936	1.51	0.2591
APP × T	0.8836	1	0.8836	6.88	0.0342
t × T	0.2162	1	0.2162	1.68	0.2355
APP^2	0.6008	1	0.6008	4.68	0.0673
t^2	2.49	1	2.49	19.44	0.0031
T^2	0.3783	1	0.3783	2.95	0.1297
R^2	0.897				
Cohesiveness (nd)					
Model	0.0451	9	0.0050	29.05	<0.0001
APP	0.0265	1	0.0265	153.20	<0.0001
t	0.0000	1	0.0000	0.1629	0.6985
T	0.0010	1	0.0010	6.00	0.0442
APP × t	0.0003	1	0.0003	1.77	0.2246
APP × T	0.0080	1	0.0080	46.40	0.0003
t × T	0.0001	1	0.0001	0.4692	0.5154
APP^2	0.0070	1	0.0070	40.70	0.0004
t^2	0.0000	1	0.0000	0.0624	0.8099
T^2	0.0017	1	0.0017	9.85	0.0164
R^2	0.973				

APP – apple puree percentage, *t* – baking time, *T* – baking temperature.

The coded factor Equations (2, 3, and 4) can be used to make predictions about muffin hardness, chewiness and cohesiveness studied for the levels of each factor. Analyzing the Equations 2, 3, and 4 corresponding to the model for each factor, a ranking of the significant factors is observed in the order of the importance of the impacts on the hardness, chewiness and cohesiveness of the muffins. The greatest positive effect on hardness (equation 2) is the interaction of the linear terms $APP \times t$, followed by the quadratic term t^2 (substituted sugar), and responsible for the greatest negative effect on hardness is the linear term *APP*, followed by the interaction of the linear terms $APP \times T$, followed by the quadratic term APP^2 > the linear term T > the quadratic term T^2 > the interaction of the terms $t \times T$.

Regarding chewiness (equation 3), the quadratic term t^2 has the greatest positive effect, followed by the interaction of the linear terms $APP \times T$ > linear term *APP* > T > quadratic term T^2 > interaction of linear terms $t \times T$ > interaction of linear terms $APP \times t$, and the interaction quadratic term APP^2 has the greatest negative effect, followed by linear term t.

In the case of cohesiveness (Equation 4), the positive effect with the greatest impact is represented by the linear term *APP*, followed by the quadratic terms $APP^2 > T^2$. On the other hand, the negative effect with the greatest impact is the interaction of the linear $APP \times T$ terms. Considering the results obtained, the hardness of the muffins was between a minimum of 7.98 N (in the case of the sample with 100% apple puree obtained by baking at 200 °C for 14 min) and a maximum of 9.99 N (for the sample with 0 puree of apples obtained by baking at 200 °C for 15 min), similar results were also obtained by Belorio et al. and Rodríguez-García et al. [31,36]. However, as the percentage of sugar substitution with apple puree increased, the hardness decreased significantly ($p < 0.05$), a phenomenon also observed by other authors. For example, Martínez-Cervera et al. [37] obtained similar results when they substituted sugar with a sucralose/polydextrose mixture in muffins [38]. Ronda et al. [38] reported similar results using polyols and oligosaccharides in sponge cake and Vatankhah [39] obtained a decrease in biscuit hardness by replacing sugar with stevioside [38,39]. In addition, Zahn et al. [40] observed a decrease in hardness when rebaundioside A was used in combination with more fibers in muffins.

Chewiness is defined as the force required a food for swallowing and directly influences the sensory perception of consumers, potentially determining the degree of acceptability and preference for certain foods. The decrease in chewiness with the increase in baking temperature could be due to the change in the structure of the starch granules [42]. In addition, the chewiness of the muffins increased with the increase in the percentage of sugar substituted with apple puree. Similar results were reported by Martínez-Cervera et al. [37], in obtaining an increase in the chewiness of the muffins by increasing the percentage of sugar substituted with erythritol [16]. Following the cohesiveness analysis, a significant influence ($p < 0.01$) of the factors and their interactions was observed (Table 3). Thus, the cohesiveness increased with the increase in the percentage of sugar substituted with apple puree, similar results were reported by Majzoobi et al. [28] by substitution with rebaudioside A.

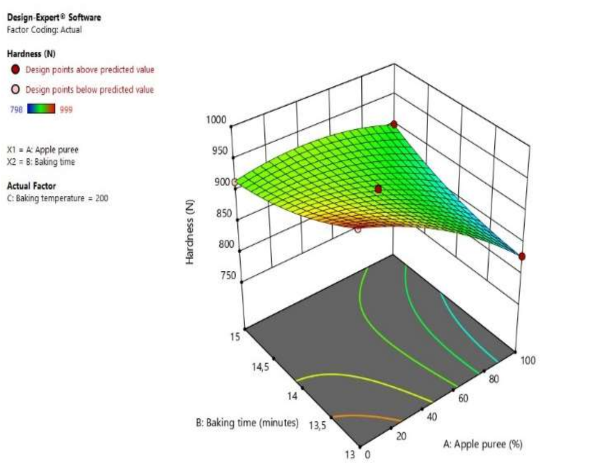
The response surfaces in Figure 1 illustrate the influence of puree percentage, baking time, and baking temperature on muffin hardness, chewiness, and cohesiveness.

From the graphs in Figure 1 d, h, l a strong correlation can be observed between the predicted and the actual values of the hardness, chewiness and cohesiveness of the muffins.

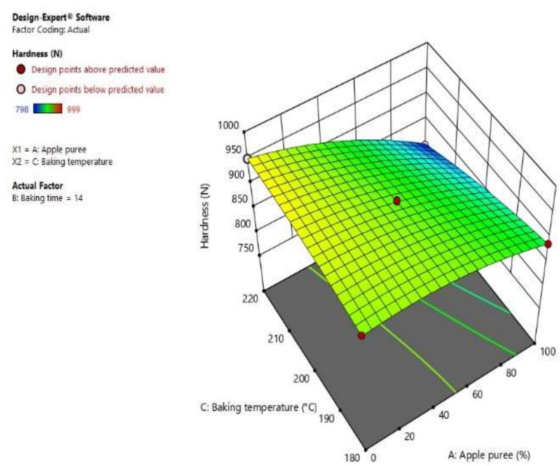
3.2. Height, volume, weight loos during baking

The 2FI model was used to represent the evolution of the height of the muffins, and the linear model was used to represent the evolution of the volume of the muffins and the baking loss of the muffins; models being chosen based on low *p*-value ($p < 0.05$), favorable Lack of Fit (non-significant) and higher coefficient of determination (R^2).

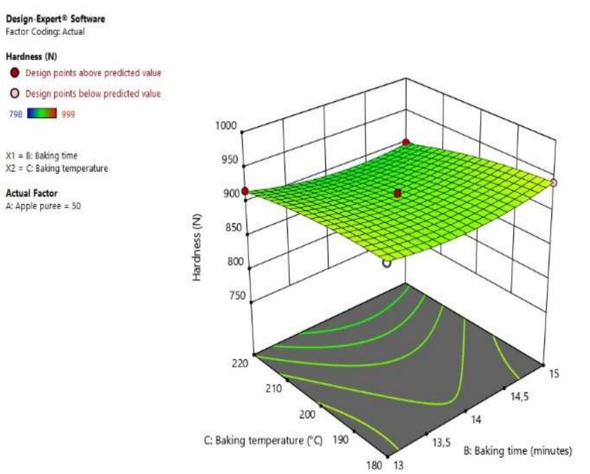
The Box-Behnken model with experimental and predicted values for muffin height, volume and baking loss are shown in Table 5.



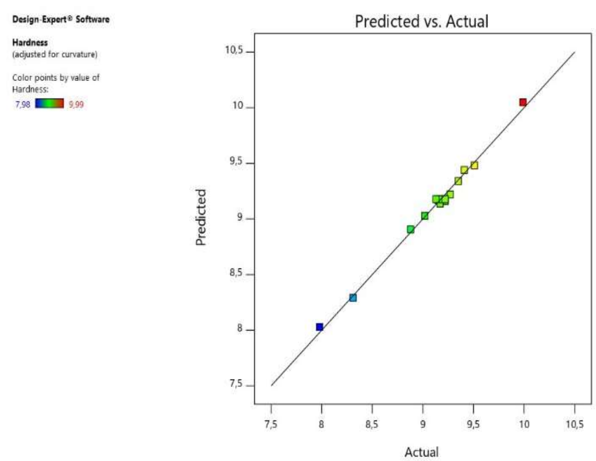
a)



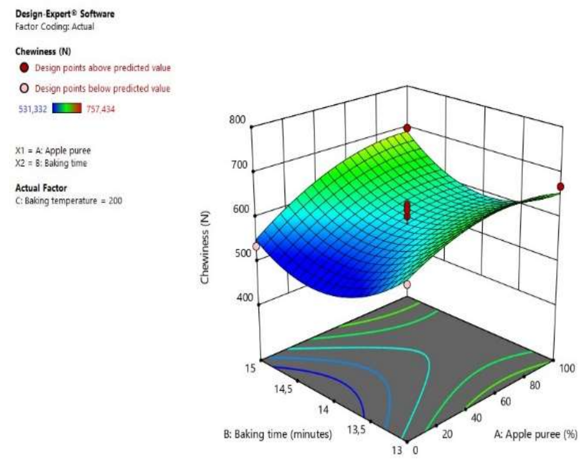
b)



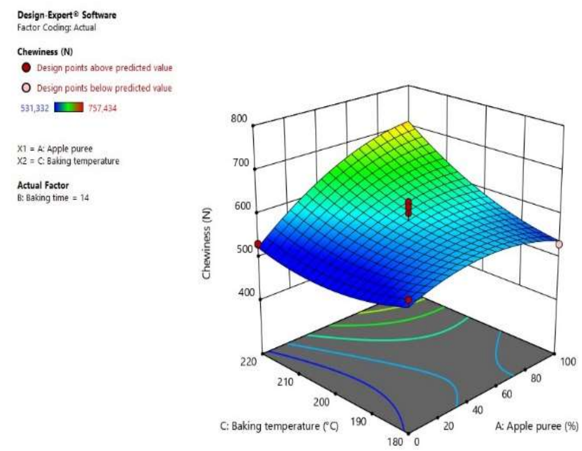
c)



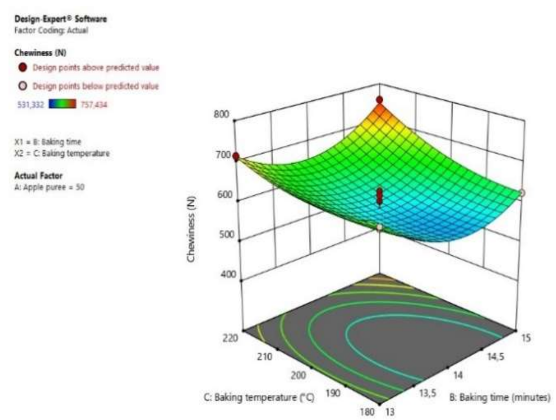
d)


Design-Expert® Software
Factor Coding: Actual
Chewiness (N)
Design points above predicted value
Design points below predicted value
531,332 757,434
X1 = A: Apple puree
X2 = B: Baking time
Actual Factor
C: Baking temperature = 200
Chewiness (N)
B: Baking time (minutes)
A: Apple puree (%)

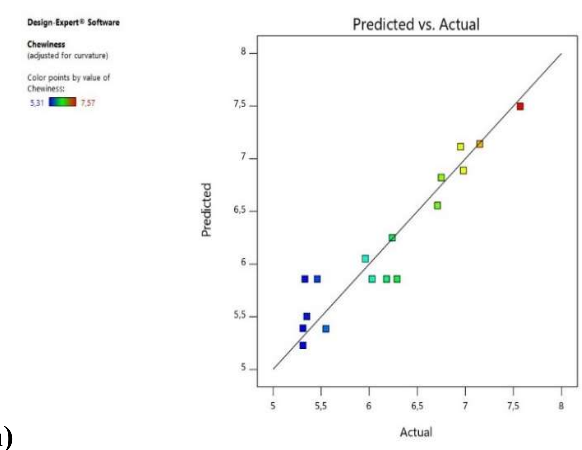
e)


Design-Expert® Software
Factor Coding: Actual
Chewiness (N)
Design points above predicted value
Design points below predicted value
531,332 757,434
X1 = A: Apple puree
X2 = C: Baking temperature
Actual Factor
B: Baking time = 14
Chewiness (N)
C: Baking temperature (°C)
A: Apple puree (%)

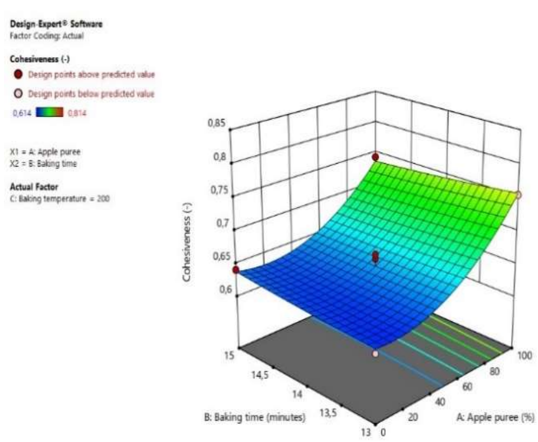
f)


Design-Expert® Software
Factor Coding: Actual
Chewiness (N)
Design points above predicted value
Design points below predicted value
531,332 757,434
X1 = B: Baking time
X2 = C: Baking temperature
Actual Factor
A: Apple puree = 50
Chewiness (N)
C: Baking temperature (°C)
B: Baking time (minutes)

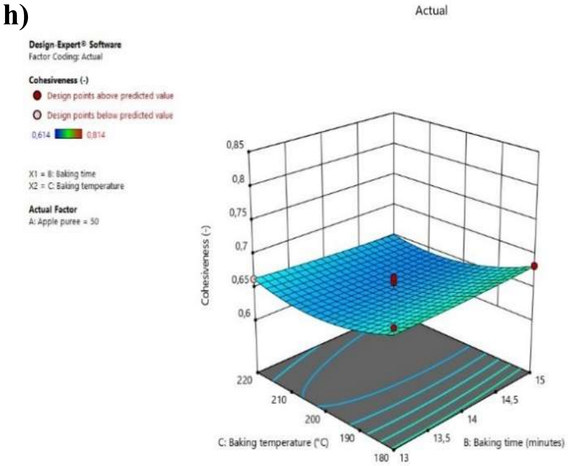
g)


Design-Expert® Software
Chewiness
(adjusted for curvature)
Color points by value of Chewiness:
5,31 7,57
Predicted vs. Actual
Predicted
Actual

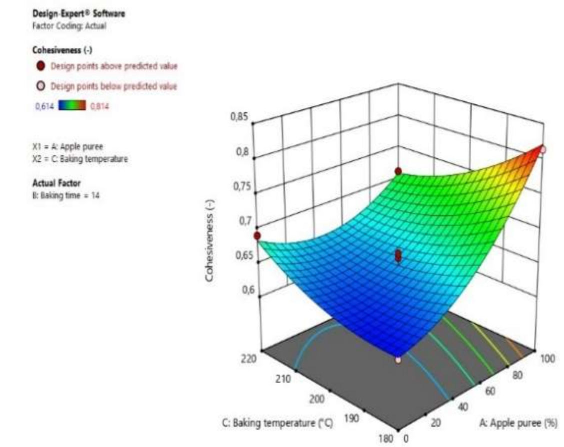
h)


Design-Expert® Software
Factor Coding: Actual
Cohesiveness (-)
Design points above predicted value
Design points below predicted value
0,614 0,814
X1 = A: Apple puree
X2 = B: Baking time
Actual Factor
C: Baking temperature = 200
Cohesiveness (-)
B: Baking time (minutes)
A: Apple puree (%)

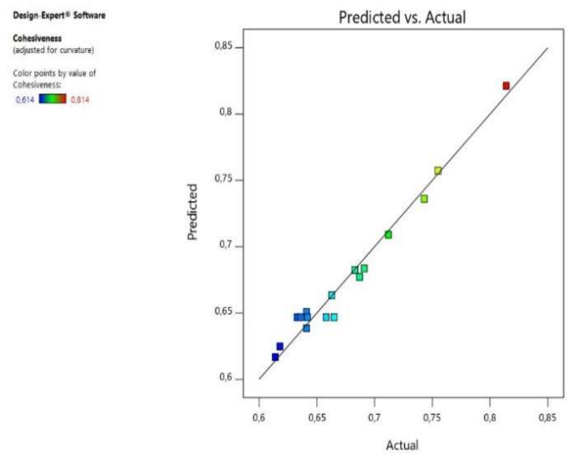
i)


Design-Expert® Software
Factor Coding: Actual
Cohesiveness (-)
Design points above predicted value
Design points below predicted value
0,614 0,814
X1 = B: Baking time
X2 = C: Baking temperature
Actual Factor
A: Apple puree = 50
Cohesiveness (-)
C: Baking temperature (°C)
B: Baking time (minutes)

j)



k)



l)

Fig. 1. Response surface plot of the influence of apple puree percentage, baking time, and baking temperature on muffin hardness (a-c), chewiness (e-g), and cohesiveness (i-k); predicted values vs. the actual values for hardness (d), chewiness (h), and cohesiviness (l)

Table 5.
Box-Behnken model with experimental and predicted values for muffin height, volume and weight loss baking

Run	Independent Variables			Measured Response			Predicted Response		
	APP (%)	t (min)	T (°C)	H (mm)	V (cm³)	WL (%)	H (mm)	V (cm³)	WL (%)
1	0	14	180	46.17	55.00	11.28	46.06	55.68	9.60
2	100	14	180	40.82	41.00	14.28	41.59	41.93	11.97
3	0	14	220	51.58	60.00	9.20	51.09	58.43	9.62
4	100	14	220	42.64	44.00	11.60	43.03	44.68	11.99
5	0	13	200	45.44	56.00	11.40	45.99	56.80	11.32
6	100	13	200	42.03	43.00	13.48	41.70	43.05	13.69
7	0	15	200	50.83	56.00	7.68	51.17	57.30	7.90
8	100	15	200	43.46	44.00	9.68	42.92	43.55	10.27
9	50	13	180	41.72	50.00	11.54	41.46	48.55	12.49
10	50	13	220	46.09	54.00	13.00	46.22	51.30	12.51
11	50	15	180	46.24	53.00	7.50	46.19	49.05	9.07
12	50	15	220	47.56	52.00	10.88	47.90	51.80	9.06
13	50	14	200	45.73	48.00	9.94	45.44	50.18	10.79
14	50	14	200	45.77	52.00	9.54	45.44	50.18	10.79
15	50	14	200	44.90	48.00	12.88	45.44	50.18	10.79
16	50	14	200	46.04	47.00	9.78	45.44	50.18	10.79
17	50	14	200	45.52	50.00	9.88	45.44	50.18	10.79

APP – apple puree percent, T – baking temperature, t – baking time, H – height, V – volume, WL – weight los

Equations 5, 6, and 7 describe the effects of puree percentage (*APP*), baking time (*t*), and baking temperature (*T*) on the height (H), volume (V), and baking weight loss (WL) of muffins.

$$\boldsymbol{Height}\ (\boldsymbol{mm}) = 45.4435 - 3.13375 \times APP + 1.615 \times T + 1.60125 \times t - 0.8975 \times APP \times T - 0.99 \times APP \times t - 0.7625 \times T \times t \quad (5)$$

$$\boldsymbol{Volume}\ (\boldsymbol{cm^3}) = 50.1765 - 6.875 \times APP + 1.375 \times T + 0.25 \times t \quad (6)$$

$$\boldsymbol{Weight\ loss}\ (\%) = 10.7965 + 1.185 \times APP + 0.01 \times T - 1.71 \times t \quad (7)$$

From the analysis of the equations, the strongest positive effect on the muffin's height is represented by the linear terms T > t, and the negative effect with the strongest impact is the linear term APP, followed by the interaction of the linear terms APP × t > APP × T > T × t. Regarding the volume, the greatest positive effect on it is represented by the linear terms T > t, and the negative effect is represented by the linear term APP. In the case of ripening loss, the linear terms APP > T have the greatest positive effect on it, and the linear term t has a negative effect.

2FI and linear models were determined to be statistically significant by analysis of variance (ANOVA). The results of the analysis of variance (Table 6) demonstrate that the chosen models explain and predict most of the variation in height (R^2 = 0.978), volume (R^2 = 0.878) and weight loss at ripening (R^2 = 0.965).

Muffin height decreased with increasing apple puree percentage and increased with baking time and temperature, while in the case of muffin volume, baking time and temperature did not cause significant changes (p < 0.01). Thus, the highest height for muffins (50.83 mm) was recorded for the sample obtained by baking at 200 °C for 15 min with 0 apple puree, and the lowest height value (40.82 mm) was recorded for the muffins obtained by baking at 180 °C for 14 min with 100% apple puree, resulting in a significant decrease (p < 0.01) in the height of the muffins with the increase in the percentage of sugar substituted with apple puree. Similar results were obtained by Rodríguez-García et al. [36] by substitution of sugar in cookies with oligofructose. By substituting sucrose in percentage of 50%, height values between 41.72 mm and 47.46 mm were obtained, similar results obtained by Gao et al. [42] by replacing sucrose with stevia in a percentage of 50%. Also, the volume of the muffins varied between 41 cm3 (for the sample obtained by substituting sugar with 100% apples puree by baking at 180 °C for 14 min) and 60 cm3 (for the sample with 0 apple puree obtained by baking at 220 °C for 14 min).

In the case of 50% sucrose substitution with apple puree, the volume varied between 47 and 54 cm^3. The volume of the muffins decreased significantly (p < 0.01) with the increase in the percentage of sugar substituted with apple puree, the results being similar to those reported by Struck et al. [43] who substituted sugar in muffins with apple fiber.

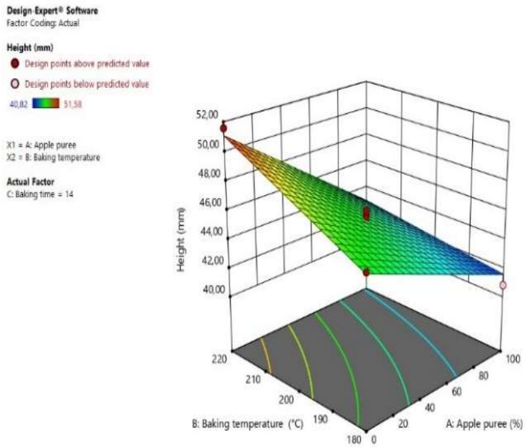
Table 6.
Analysis of variance (ANOVA) for polynomial model in muffin height, volume and baking loss

Height (mm)					
Source	**Sum of Squares**	**df**	**Mean Square**	***F*-value**	***p*-value**
Model	129.41	6	21.57	75.56	<0.0001
APP	78.56	1	78.56	275.21	<0.0001
T	20.87	1	20.87	73.10	<0.0001
t	20.51	1	20.51	71.86	<0.0001
APP × T	3.22	1	3.22	11.29	0.0072
APP × t	3.92	1	3.92	13.73	0.0041
T × t	2.33	1	2.33	8.15	0.0171
R^2	0.978				
Volume (cm^3)					
Model	393.75	3	131.25	31.18	<0.0001
APP	378.12	1	378.12	89.83	<0.0001
T	15.13	1	15.13	3.59	0.0805
t	0.5000	1	0.5000	0.1188	0.7359
R^2	0.878				
Weight loss (%)					
Model	34.63	3	11.54	6.18	0.0077
APP	11.23	1	11.23	6.02	0.0290
T	0.0008	1	0.0008	0.0004	0.9838
t	23.39	1	23.39	12.53	0.0036
R^2	0.965				

Increasing the baking time caused a small loss in the baked weight of the muffins, and baking time did not cause significant changes in the baked weight loss of the muffins ($p < 0.01$).The increase in baking weight loss with increasing percentage of sugar substituted with apple puree could be due to the higher water binding capacity of sugar than apple puree, similar results being reported by Rodríguez-García et al. [36] following the substitution of sugar in the cake with oligofructose.

The response surfaces in Figure 2 illustrate the influence of puree percentage, baking time, and baking temperature on height, volume and baking loss of the muffins.

From the graphs in Figure 2 d, f, h a strong correlation can be observed between the predicted and the actual.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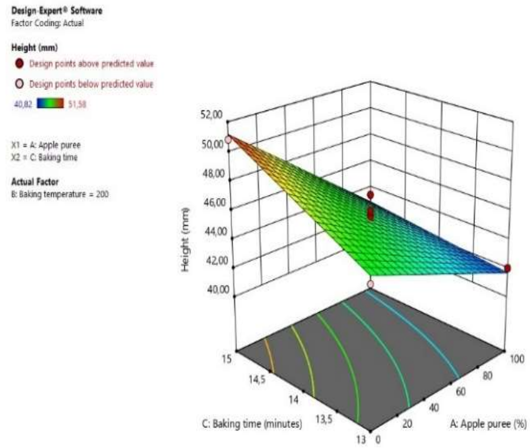
Design points below predicted value
40,82
51,58
X1 = A: Apple puree
X2 = B: Baking temperature
Actual Factor
C: Baking time = 14
Height (mm)
52,00
50,00
48,00
46,00
44,00
42,00
40,00
220
210
200
190
180
B: Baking temperature (°C)
0
20
40
60
80
100
A: Apple puree (%)

a)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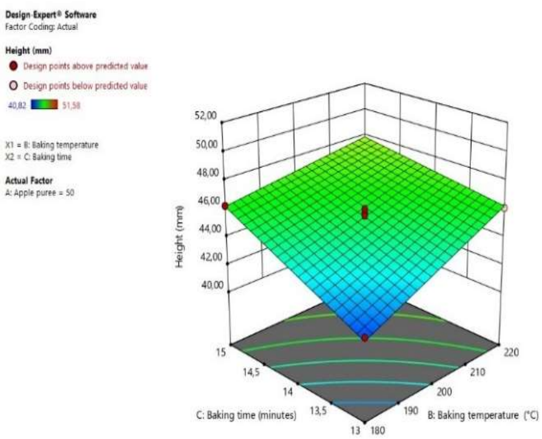
Height (mm)
Design points above predicted value
Design points below predicted value
40,82
51,58
X1 = A: Apple puree
X2 = C: Baking time
Actual Factor
B: Baking temperature = 200
Height (mm)
52,00
50,00
48,00
46,00
44,00
42,00
40,00
15
14,5
14
13,5
13
C: Baking time (minutes)
0
20
40
60
80
100
A: Apple puree (%)

b)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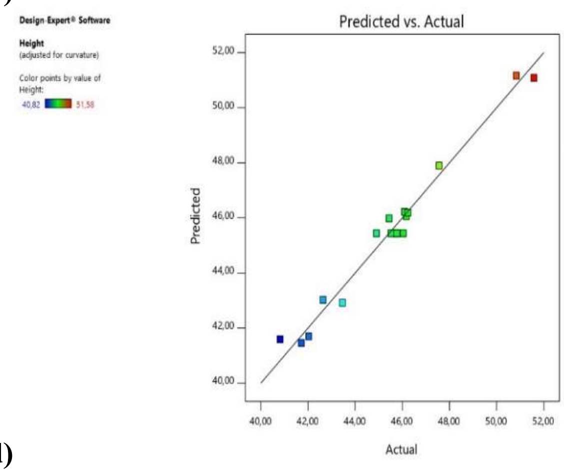
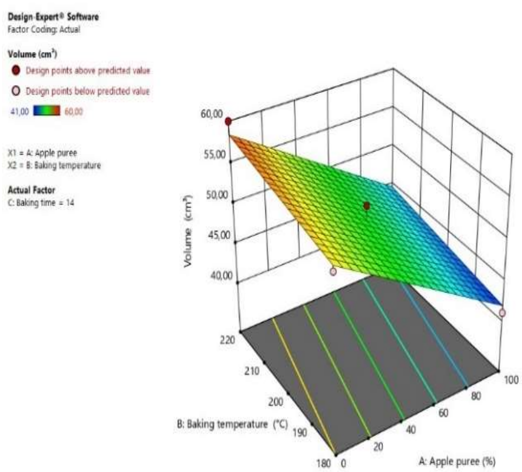
Factor Coding: Actual
Height (mm)
Design points above predicted value
Design points below predicted value
40,82
51,58
X1 = B: Baking temperature
X2 = C: Baking time
Actual Factor
A: Apple puree = 50
Height (mm)
52,00
50,00
48,00
46,00
44,00
42,00
40,00
15
14,5
14
13,5
13
C: Baking time (minutes)
180
190
200
210
220
B: Baking temperature (°C)

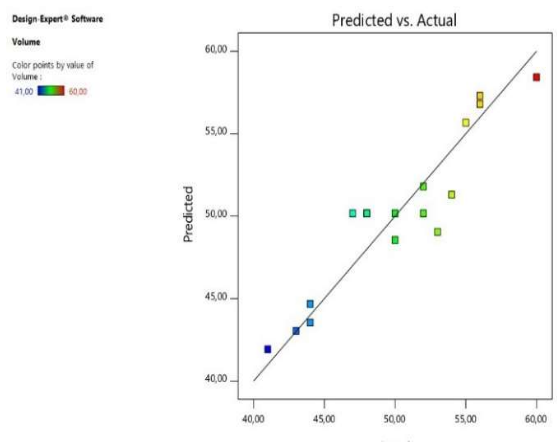
c)


Design-Expert® Software
Height
(adjusted for curvature)
Color points by value of
Height:
40,82
51,58
Predicted vs. Actual
Predicted
52,00
50,00
48,00
46,00
44,00
42,00
40,00
Actual
40,00
42,00
44,00
46,00
48,00
50,00
52,00

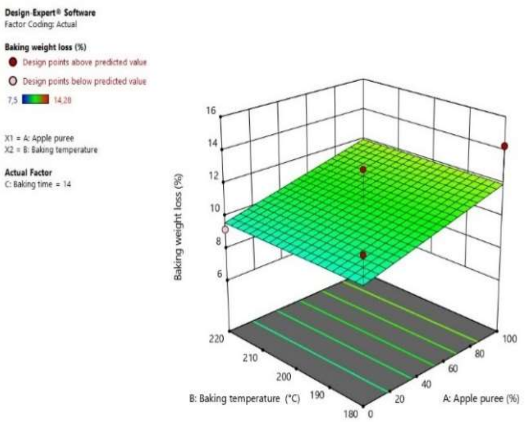
d)

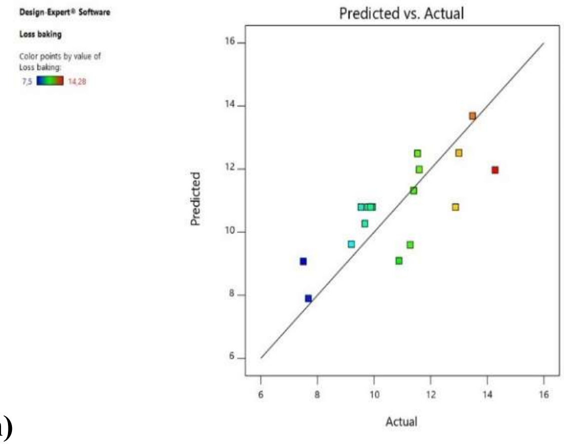

Design-Expert® Software
Factor Coding: Actual
Volume (cm³)
Design points above predicted value
Design points below predicted value
41,00
60,00
X1 = A: Apple puree
X2 = B: Baking temperature
Actual Factor
C: Baking time = 14
Volume (cm³)
60,00
55,00
50,00
45,00
40,00
220
210
200
190
180
B: Baking temperature (°C)
0
20
40
60
80
100
A: Apple puree (%)

e)


Design-Expert® Software
Volume
Color points by value of
Volume :
41,00
60,00
Predicted vs. Actual
Predicted
60,00
55,00
50,00
45,00
40,00
Actual
40,00
45,00
50,00
55,00
60,00

f)





g) **h)**

Fig. 2. Response surface plot of the influence of apple puree percentage (*APP*), baking time (*t*), and baking temperature (*T*) on muffin height (a-c), volume (e) and baking weight loss (g); predicted values vs. the actual values for height (d), volume (h) and baking weight loss (h)

3.3. Sensory analysis

Regarding the sensory analysis and consumer acceptability of the functional muffins, Figure 3 shows the results of the six sensory parameters evaluated. For these parameters, there were no significant differences ($p < 0.05$) between muffins in which apple puree sugar was or was not substituted.

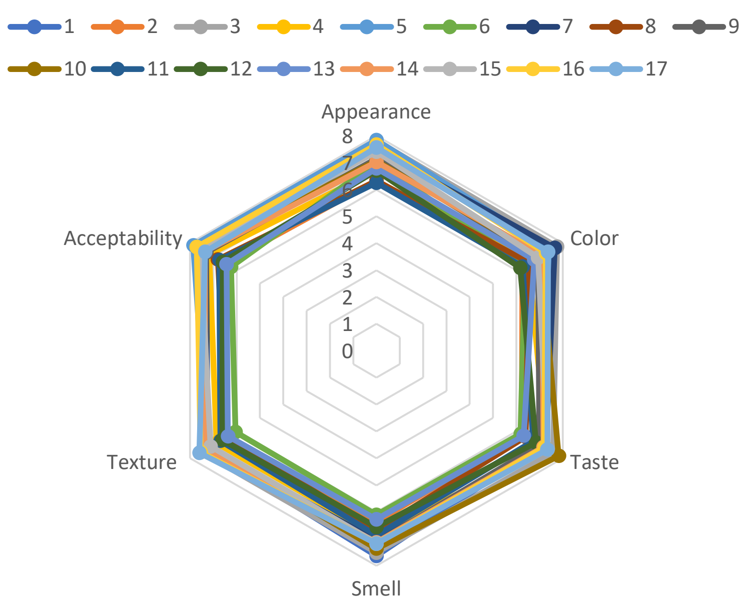


Fig. 3. **Spider web plot of six descriptive sensory attributes of muffins with or without addition of apple puree**

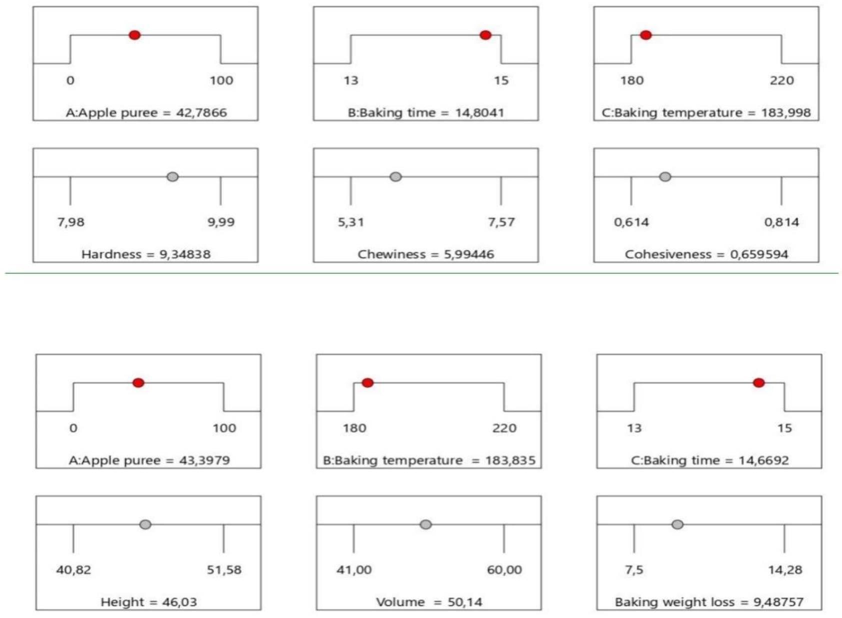


Fig. 4. Ramp plots illustrating the optimal solution that best satisfies the given conditions. This solution was determined by the desirability function implemented in Design Expert version 11 software

Optimization was performed to obtain muffins with textural, physical and sensory properties acceptable to consumers. A numerical optimization function was used to find the composition that simultaneously provides maximum desirability for the chosen attributes (Figure 4).
Figure 5 shows the amplitude of the desirability function for the optimization of muffins and for each response studied. The desirability values on the graph in Figure 5 indicate how close a response is to its ideal value. For a desirability value of 1, the results reach the ideal value. The desirability of the optimization performed for the process (independent) and response variables, combined, has a satisfactory value of 0.977.
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Taking into account all the quality characteristics and following the optimization procedure of the Design Expert program in which the sugar inclusion levels were minimized, a muffin formulation was provided with the following technological parameters: sugar can be replaced in percentages between 42.78-43.39%, baking time between 14.66 and 13.80 min, and the baking temperature between 183.83 and 183.99 °C.

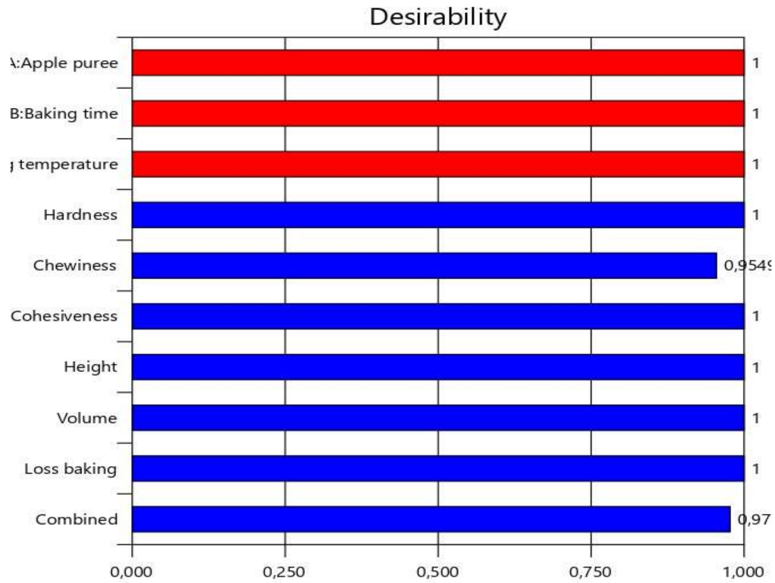

Fig. 5. The desirability function of optimization

4. Conclusions

Optimization of obtaining functional muffins by the response surface method was successful. The use of apple puree allowed a 50% reduction in sucrose. Changing the percentage of sucrose substituted with apple puree in the functional muffins had a significant effect ($p < 0.05$) on the firmness, chewiness, cohesion, height, volume and weight loss on baking of the final product.

The percentage of apples, baking time and baking temperature of the muffins were optimized to achieve maximum textural values for firmness, chewiness and cohesiveness. Thus, optimal value for hardness of 9.34 N, chewiness 5.99 N and cohesiveness 0.65 resulted from replacing sugar with applesauce 42.78% and baking at 183.99 °C for 14.80 min.

The muffins obtained under the mentioned technological conditions are qualitative in terms of texture, physical and sensory properties.

Substituting about 50% of the initial sugar in the muffin recipe with apple puree significantly reduces the energy value of the final product and brings significant nutritional benefits due to its vitamins, minerals and fiber content, transforming muffins from a product rich in empty calories into a healthier and more nutritious option, while retaining the sweet taste and soft texture.

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