OPTIMIZATION OF THE TEXTURE OF FAT-BASED SPREAD CONTAINING HULL-LESS PUMPKIN (Cucurbita pepo L.) SEED PRESS-CAKE

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Hull-less pumpkin seed press-cake, a by-product of the pumpkin oil pressing process, was used to formulate a fat-based spread which resembled commercial peanut butter; both in the appearance and in texture. In this study, response surface methodology was used to investigate the effects of a commercial stabilizer and cold-pressed hemp oil added to the pumpkin seed press-cake, on the texture of the formulations using instrumental texture profile analysis. The responses were significantly affected by both variables tested in a central composite, two factorial experimental design on five levels. Strong and firm spreads, without visible oil separation were formed and had an appearance and texture comparable to commercial peanut butter. In terms of the primary food texture attributes such as hardness, cohesiveness and adhesiveness, determined by the instrumental texture analysis, the optimum combination of variables with 1-1.2% of added stabilizer and 20-40% of added hemp oil (in the oil phase) produced desirable spreads.

KEY WORDS: fat-based spread, hull-less pumpkin seed press-cake, instrumental texture profile analysis, optimization, response surface methodology

INTRODUCTION

Food processing wastes are usually burned, or used in low value applications, such as fertilizers and animal feed. The food industry is oriented toward greater value-added products, including the nutraceutical and chemical uses for its waste materials. Oilseed press-cakes obtained by mechanical pressing contain substantial amounts of residual oil and are rich in protein, nutrients, and minerals. Some press-cakes have a strong potential as sources of value-added, nutritious food products or ingredients. Pumpkin (Cucurbita pepo L.) seed oil has been well known and used as salad oil in a number of European countries such as Austria, Slovenia, Croatia, Hungary and Serbia. Pumpkin seed oil can be processed as either cold pressed or prepared as virgin oil (from roasted seeds).

This oil has components which have positive effects on the human body, including antidiabetic, antihypertensive, antitumor, antibacterial, antihypercholesterolemia, and an-

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ti-inflammatory actions, to name a just few (1). Two varieties of seeds can be used: seeds with hull or hull-less seeds. Hull-less (also known as “naked”) pumpkin seed oil cake can be used in food, since all components of the cake are edible.

There has been a considerable amount of research reported on the composition of pumpkin seed oil and pumpkin seed flours of different varieties of pumpkin (2, 3). However, only a few studies have been published on Cucurbita pepo L. seed oil cake (4, 5). Cold pressed hemp (Cannabis sativa L.) oil contains significant levels of natural antioxidants (γ-tocopherol and α-tocopherol), phenolic compounds, and γ-linolenic acid that provide health benefits, including the lowering of cholesterol and high blood pressure. This oil showed high kinetic stability during heating and cooling (6). Chia (Salvia hispanica L.) seeds are rich in oil, protein and mucilage, which is a type of fiber that can form gel structure with water and oil. Its oil is very high in omega-3 fatty acids (7).

Oilseed spreads have been widely accepted in the market. Peanut butter is the most widely produced oilseed spread. There are reports on sunflower butter preparation (8, 9), peanut butter and chocolate spreads optimization (10, 11, 12), as well as on investigation of other types of spreads, where instrumental texture analysis was used to assess the quality of spreads (13-17). The texture properties of spreads, such as hardness (spreadability), cohesiveness (consistency) and adhesiveness (stickiness) are commonly used to describe the spread’s quality, and to predict consumer acceptance. According to Szczesniak (18), hardness, cohesiveness, viscosity and elasticity (springiness), as mechanical characteristics of food, are related to forces of attraction acting between particles of food and opposing disintegration. Adhesiveness is, however, related to the surface properties of food (18). These textural properties, as related to deformation, disintegration and flow of spreads under the application of force, are measured using instrumental methods as functions of stress, time, and distance (19). In addition to the above five primary parameters, there are two additional secondary parameters that describe texture of spreads: chewiness and gumminess. However, springiness index and stringiness length can also be used to describe the texture of spreads. Instrumental texture profile analysis (TPA) is a “two-bite-test” which provides textural parameters that correlate well with sensory evaluation parameters, where the force-time curves are analyzed (20). Definitions used in this work of both primary and secondary TPA parameters, were adopted from Szczesniak (18) and the Brookfield’s instruction manual (21) and are presented in the discussion section.

In our opinion, instrumental methods are preferred to sensory panel tests, mostly because they are believed to be more objective, reproducible and require less time. Significant correlations were found between the instrumental texture measures and sensory characteristics of peanut-based spreads (22). Lee and Resurreccion (23) have studied peanut butter texture and correlated the sensory and instrumental TPA measurements. The texture prediction equations developed in their study were verified by the sensory tests, which successfully confirmed eleven sensory texture attributes predicted from instrumental TPA results. However, in the experiments involving evaluation by the sensory panel, it is important to ensure that the differences generated by the experimental variations are sufficiently large to be detected by the sensory panelists (24).

Research on rheological behavior of peanut butter indicates that the yield stress directly relates to the spreadability of the product. It has been shown that an approximate
estimate of subjective spreadability can be designed using state (25). These results were corroborated by Singh et al. (26) who showed that reduced-fat peanut pastes display non-Newtonian, time-independent, shear-thinning behavior when subjected to steady shear flow. Yield (peak) stress is directly correlated to the hardness of the product in the instrumental TPA. The mathematical definition for the peak stress is: the stress at the hardness point of the first compression stroke, where stress is calculated as the load at a given point, divided by the sample’s cross-sectional area. Therefore, the instrumental TPA hardness directly relates to the spreadability of the product.

Use of stabilizers in peanut butter and other spreads is very important in order to achieve a firm but spreadable texture without oil separation during the acclaimed shelf life, where a choice (type) of stabilizer plays a crucial role (27). Response surface methodology (RSM) has been widely used in the optimization of food processes to define the relationships between the responses and independent variables (28). Experimental factorial design was successfully used in the past to model the process and optimize formulations and processing conditions of spreads (9). Contents of stabilizer and oil (in addition to additive as a third variable) were used as input variables to study instrumental texture profiles of a low peanut spread (29).

To the best of our knowledge, no data have been reported on the preparation of food grade spreads and subsequent instrumental texture analysis to optimize spread formulations from hull-less pumpkin seed oil press-cake. The specific objectives of this study were: 1) to investigate the effect of the added hemp oil and commercial stabilizer on the instrumental TPA of this novel spread; 2) to match the texture and appearance of the product to commercially available peanut butter with no oil separation and 3) to determine an optimum formulation in respect to the stabilizer and hemp oil content, for the manufacture of such spread.

EXPERIMENTAL

Materials and methods

A sample of hull-less pumpkin (Cucurbita pepo L) seed press-cake, a by-product of the pumpkin oil pressing process, was obtained from a small company that uses traditional mechanical oil pressing technology. Cold pressed hemp (Cannabis sativa L.) oil, chia (Salvia hispanica L.) seeds, sea salt and white sugar were purchased from local supermarkets. High oleic sunflower oil (Trisun 80); a commercial stabilizer Dritex RC (a blend of hydrogenated canola and coconut oils); maltodextrin (Star DR 100) and emulsifier/stabilizer (Myvatex Monoset K, a blend of distilled monoglycerides and hydrogenated canola oil, cottonseed and palm oils) were donated by Nealanders International Inc., Mississauga (Ontario). One peanut butter sample, that did not exhibit oil separation at the time of purchase, was chosen as a control (PBK).

Spreads preparation

Batches of spreads (1 kg each) were prepared according to the experimental design (Table 1). The procedure for preparing the pumpkin seed press-cake spreads was as fol-
lows: a mixture of dry ingredients consisting of press-cake (54.8%), maltodextrin (1.6%), sugar (3.2%), salt (0.6%), and chia seeds flour (4.2%) was thoroughly blended using a laboratory mixer. Once mixed, the mixtures were stored at ambient temperature for 24 h. This mixture was of the same composition for all spreads prepared. The liquid oil phase consisted of hemp oil and high oleic sunflower oil (oils in varying proportions, as per experimental design - Table 1) which made up 33.7% (w/w) of the total formulation. The quantity of the hemp oil was a variable whose influence on the instrumental TPA was investigated, while high oleic sunflower oil was the second oil added to make up to the required amount of oil for spread manufacturing. Commercial stabilizer Dritex RC (0.8-1.6%, w/w) and emulsifier Myvatex Monoset K (0.7%, w/w) were added to the heated oil blend (70-80°C) until complete dissolution. The liquid oil phase was added slowly to the dry mix, and it was blended for 4 minutes at the low speed. All spread samples were homogenized in a double-wall vessel (kept at 80°C with hot water flowing) with a high-shear mixing (Black and Decker Power Pro). Hot spreads were immediately filled into polypropylene containers (150 g) and tapped to remove air bubbles. All samples were stored at ambient temperature (21°C) in closed containers. All analytical measurements were performed in triplicate within one week.

**Texture evaluation**

For two-cycle compression, a Texture Analyzer model CT3 (Brookfield Engineering Laboratories, Inc., Middleboro, MA, USA) was used to obtain the force-time curves. The method for texture profile analysis (TPA) was used as recommended in the Brookfield’s instruction manual. The Texture Analyzer was supplied with a load cell of 4.5 kg and the application software (Brookfield Texture PRO CT®). Three successive compressions were carried out on each sample. The resulting force-time curves were developed for hardness, cohesiveness and adhesiveness. The accessory used for all measurements was a cone shaped acrylic probe (TA2/100, 14g with 45° angle). The sample was directly measured in the original container (cylindrical shape: 30 mm depth and 86 mm internal diameter) at the test and return speed of 1 mm/s and target depth of 20 mm. Trigger load was 4.0 g, pretest speed 2 mm/s and data rate was 100 points/s. Upon two compression cycles, the probe was automatically returned to the initial starting point and the Texture Analyzer was reset for the next test. All analyses were conducted at ambient temperature. The force-time deformation curves during compression and decompression cycles were obtained each time. All results were expressed in a report with values automatically calculated by the software.

**Experimental design and statistical analysis**

RSM was used to investigate the effects of stabilizer and hemp oil content on the product responses (instrumental TPA texture) of all spreads. A five-level, two variable, central composite design with α=2 was used, resulting in 13 combinations with two replications. The independent variables were stabilizer content (X₁, % of the total weight, w/w) and hemp oil content (X₂, % of the added oil, w/w). These variables were coded at the levels of -2, -1, 0, +1 and +2 (30). Actual and coded values of variation levels are shown in Table 1.
Table 1. Coded values and treatment levels for the pumpkin oil seed press-cake spreads

<table>
<thead>
<tr>
<th>Variable</th>
<th>Symbol</th>
<th>Coded/Uncoded variables levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stabilizer content (%)</td>
<td>X&lt;sub&gt;1&lt;/sub&gt;</td>
<td>-2, -1, 0, +1, +2</td>
</tr>
<tr>
<td>Hemp oil content (%)</td>
<td>X&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.8, 1.0, 1.2, 1.4, 1.6</td>
</tr>
</tbody>
</table>

<sup>a</sup> X<sub>i</sub> = % of the formula total weight, w/w; <sup>b</sup> X<sub>j</sub> = % of the total added oil, w/w

The combinations included a formulation with an intermediate level (central point) of the two variables replicated four times, which was used to determine inherent variance in the technique. Experiments were randomized in order to minimize the systematic bias in the observed responses due to extraneous factors and to increase precision. Dependent variables were hardness, cohesiveness, springiness, adhesiveness, gumminess, chewiness, stringiness length and springiness index, as product responses. RSM was applied to experimental data using a commercial statistical package Design-Expert<sup>®</sup> version 7.1 software for Design of Experiments (Stat-Ease, Inc., Minneapolis, MN, USA) for the generation of response surface plots. Experimental data were fitted by a second-order polynomial model:

\[ Y_i = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2, \]  

where \( Y_i \) was a response, \( X_1 \) stabilizer content (w/w), \( X_2 \) hemp oil content (w/w) and \( b_0, b_1, b_2, b_{11}, b_{22} \) and \( b_{12} \) were the regression coefficients.

The multiple regression analysis was conducted using the same software that was used for the design of the experiment. The response surfaces and contour plots for these models were plotted as a function of two variables. Data were obtained as means ± standard deviations (SD) for each sample analyzed in triplicate. Statistical significance of the terms in regression equation was examined by analysis of variance (ANOVA) for each response. The proportion of variance explained by the polynomial models obtained was given by the coefficient of determination (R<sup>2</sup>). Fisher’s F-test was used for the determination of the significance of the model and individual effects for each of the coefficient estimates (F-test, at \( p \leq 0.05, p \leq 0.01 \) and \( p \leq 0.001 \)). For any of the model terms, a large regression coefficient (R<sup>2</sup> > 0.8) and a small p-value (at least \( p<0.05 \)) indicated a more significant effect on the respective response variables. The experimental results were compared to the texture measurements of a commercial peanut butter (PBK). This study was based on a hypothesis that the instrumental hardness, cohesiveness, springiness, adhesiveness, gumminess, chewiness, stringiness length and springiness index of the spreads were functionally related to the components content. Optimum component content for each model was estimated by the desirability method using Design-Expert<sup>®</sup> version 7.1 software.

RESULTS AND DISCUSSION

The effect of the stabilizer and hemp oil content on texture attributes of the prepared spreads was analyzed using the RSM methodology. Experimental design and results
obtained based on the force-deformation curves during instrumental TPA analysis are shown in Table 2.

Table 2. Central composite design arrangement and responses of instrumental texture analysis: hardness (Y1), cohesiveness (Y2) and adhesiveness (Y3) for all tested spreads and commercial peanut butter sample (PBK)

<table>
<thead>
<tr>
<th>Run</th>
<th>X1 (Stabilizer %)</th>
<th>X2 (Hemp Oil %)</th>
<th>Y1 (g)</th>
<th>Y2</th>
<th>Y3 (mJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PBK</td>
<td>0</td>
<td>0</td>
<td>451.33±13.05</td>
<td>0.32±0.02</td>
<td>4.33±0.35</td>
</tr>
<tr>
<td>1</td>
<td>1.0</td>
<td>40</td>
<td>581.00±8.41</td>
<td>0.18±0.02</td>
<td>3.80±0.82</td>
</tr>
<tr>
<td>2</td>
<td>1.4</td>
<td>40</td>
<td>1000.50±36.01</td>
<td>0.14±0.01</td>
<td>2.96±1.11</td>
</tr>
<tr>
<td>3</td>
<td>1.0</td>
<td>80</td>
<td>852.17±28.00</td>
<td>0.13±0.01</td>
<td>2.33±0.40</td>
</tr>
<tr>
<td>4</td>
<td>1.4</td>
<td>80</td>
<td>1079.33±26.37</td>
<td>0.14±0.00</td>
<td>2.69±0.18</td>
</tr>
<tr>
<td>5</td>
<td>0.8</td>
<td>60</td>
<td>649.33±21.36</td>
<td>0.16±0.01</td>
<td>3.42±0.48</td>
</tr>
<tr>
<td>6</td>
<td>1.6</td>
<td>60</td>
<td>947.00±43.01</td>
<td>0.14±0.01</td>
<td>2.61±0.23</td>
</tr>
<tr>
<td>7</td>
<td>1.2</td>
<td>20</td>
<td>565.00±11.27</td>
<td>0.18±0.01</td>
<td>3.75±0.17</td>
</tr>
<tr>
<td>8</td>
<td>1.2</td>
<td>100</td>
<td>713.01±23.57</td>
<td>0.15±0.01</td>
<td>2.83±0.57</td>
</tr>
<tr>
<td>9</td>
<td>1.2</td>
<td>60</td>
<td>905.83±28.36</td>
<td>0.12±0.01</td>
<td>1.93±0.62</td>
</tr>
<tr>
<td>10</td>
<td>1.2</td>
<td>60</td>
<td>909.82±15.13</td>
<td>0.12±0.00</td>
<td>1.95±0.17</td>
</tr>
<tr>
<td>11</td>
<td>1.2</td>
<td>60</td>
<td>907.73±18.35</td>
<td>0.12±0.01</td>
<td>1.99±0.13</td>
</tr>
<tr>
<td>12</td>
<td>1.2</td>
<td>60</td>
<td>912.29±4.36</td>
<td>0.13±0.01</td>
<td>1.98±0.31</td>
</tr>
<tr>
<td>13</td>
<td>1.2</td>
<td>60</td>
<td>908.43±8.78</td>
<td>0.11±0.01</td>
<td>1.85±0.35</td>
</tr>
</tbody>
</table>

a Reported values are means of three determinations ± SD; b X1 = stabilizer % of the formula total weight, w/w; c X2 = hemp oil % of the total added oil, w/w; d Control sample, as target; e Treatment used as a control run (central point of the design)

In some cases, reduced models were presented if certain variables were insignificant for the model, based on the results of ANOVA. It is important to note that the appearance of all samples was very similar to peanut butter and that after 7 days none of the samples stored at ambient temperature (21 °C) exhibited any (visible) oil separation. The control sample (commercial peanut butter) was evaluated at the same time as the spreads. Results are presented in Table 2.

TPA hardness

Hardness (firmness) is the maximum force required to compress a food between the molars and the force necessary to attain a given deformation. The mathematical definition for hardness is: maximum load value of the compression cycle. As indicated earlier, the high value of hardness also means low spreadability of the test product. Spreadability, defined as the ability to apply a spread on a piece of bread or cracker, is probably the most important textural value of any spread and is expressed in terms of hardness. In this study, a multiple linear regression equation of a second-order polynomial model was generated relating hardness as a system parameter to the variable coded levels. The target for the hardness model was minimized, since our goal was to imitate the spreadability of
PBK. The regression model presented in equation (2) allowed for prediction of the effects of independent variables on hardness:

\[
\text{TPA Hardness (g)} = 923.96 + 103.50X_1 + 53.83X_2 - 48.10 X_1X_2 - 25.75 X_1^2 - 65.54X_2^2 [2]
\]

Hardness of spreads varied between the samples, from 565.00 ± 11.27 to 1079.33 ± 26.37 g.

**Figure 1.** Response surface plots for TPA analysis of the prepared spreads: (a) hardness, (b) cohesiveness and (c) adhesiveness, as affected by the stabilizer and hemp oil content

Figure 1a shows that the hardness increased with the increase of stabilizer content, which is consistent with other studies (10). However, the hardness also increased with the
increase of the hemp oil content. This is probably a result of the higher content of the saturated fatty acids introduced by hemp oil, which interacted with the stabilizer crystals (a blend of saturated oils) to form a firmer structure. The multiple regression model for predicting hardness could explain 87% of the observed variations. The F-value of 9.74 with an overall model p < 0.0049 implies that the model is appropriate, providing a good agreement between the predicted and the actual values for TPA hardness. Both variables $X_1$ and $X_2$ were significant model terms (Table 3).

**Table 3.** Significance of the regression models (F-values) and the effects of processing variables on the instrumental texture properties of prepared spreads: hardness ($Y_1$), cohesiveness ($Y_2$) and adhesiveness ($Y_3$)

<table>
<thead>
<tr>
<th>Sources of variance</th>
<th>$Y_1$</th>
<th>$Y_2$</th>
<th>$Y_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b_1$</td>
<td>22.99***</td>
<td>9.70***</td>
<td>n.s.</td>
</tr>
<tr>
<td>$b_2$</td>
<td>6.22**</td>
<td>23.96*</td>
<td>12.70***</td>
</tr>
<tr>
<td>$b_{12}$</td>
<td>n.s.</td>
<td>14.85***</td>
<td>n.s.</td>
</tr>
<tr>
<td>$b_{11}$</td>
<td>n.s.</td>
<td>31.88*</td>
<td>19.99***</td>
</tr>
<tr>
<td>$b_{22}$</td>
<td>17.60***</td>
<td>70.78*</td>
<td>31.77*</td>
</tr>
<tr>
<td>Model F - value</td>
<td>9.74</td>
<td>26.17</td>
<td>12.15</td>
</tr>
<tr>
<td>Model p – value</td>
<td>0.0047</td>
<td>0.0002</td>
<td>0.0024</td>
</tr>
<tr>
<td>CV (%)</td>
<td>8.91</td>
<td>4.63</td>
<td>11.84</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.8743</td>
<td>0.9492</td>
<td>0.8967</td>
</tr>
</tbody>
</table>

$b_1$, $b_2$ – linear regression coefficients; $b_{12}$ – interaction regression coefficient; $b_{11}$, $b_{22}$ – quadratic regression coefficients; CV – coefficient of variation; $R^2$ – model regression coefficient

*Significant at p ≤ 0.001; **Significant at p ≤ 0.05; ***Significant at p ≤ 0.01; n.s. - not significant at p ≤ 0.05

The component variables and quadratic effect of hemp oil content showed significant influence on the hardness of the spreads. Overall, stabilizer content significantly affected hardness (Figure 1a) and provided stability of the spreads in terms of the absence of oil separation on the surface. The coefficient of variation (CV) is the ratio of the standard error of estimate to the mean value of observed response expressed as a percentage and it is a measure of reproducibility of the models. As a general rule, the CV should be no greater than 10%. In our case, the CV value was 8.91. Verification of the model was conducted by evaluating sample no. 7 (1.2 % stabilizer and 20% hemp oil added) and no. 1 (1.0 % stabilizer and 40% hemp oil added), where the predicted hardness value of sample no. 7 of 554.13 g was very close to the observed value of 565.00±11.27 g and the closest to 451.33±13.05 g, the hardness of the control sample, PBK. The optimum formulation was one with the lowest level of hemp oil added (sample no. 7). On the basis of the analysis of variance and comparison of actual with the predicted values, it can be concluded that the selected model adequately represents the data for the instrumental TPA hardness (spreadability) of this spread.
TPA cohesiveness

Cohesiveness (consistency) indicates the strength of internal bonds making up the body of food and the degree to which a food can be deformed before it breaks. The analysis of variance showed that the regression model was sufficiently accurate for all responses, with values $R^2=0.9242$ and $p<0.0008$. On the basis of the analysis of variance, a reduced model is presented. The relationship between the independent variables and cohesiveness can be described by equation (3):

$$\text{TPA Cohesiveness} = 0.097 - 0.025X_1 + 0.025X_1X_2 + 0.012X_1^2 + 0.025X_2^2 \quad [3]$$

Stabilizer content had a significant negative linear effect ($p < 0.0016$), whereas its significant quadratic effect ($p < 0.011$) was positive. The same effect was observed for the hemp oil content (Figure 1b). Thus, at lower contents of hemp oil and stabilizer, the values of cohesiveness were the highest. This is probably due to the formation of a more compact internal structure, where all available liquid oil was incorporated into the protein/carbohydrate matrix, which increased the strength of internal bonds. The interaction between the stabilizer and hemp oil increased the cohesiveness. P-value for variables (Table 3) indicated that all variables are significant model terms, except for the linear effect of the hemp oil content. The largest value of the estimated regression coefficient for the stabilizer content ($b_1=0.025$) was the most important linear variable influencing the instrumental TPA cohesiveness of the spreads. In order to optimize the variables with the cohesiveness values similar to that of PBK, the target for the TPA cohesiveness model was maximized, and the predicted model showed the best model fit for the stabilizer content of 1.0% and hemp oil content of 40%. As shown in Table 2, samples no. 1 and 7 had the highest consistency, with the values closest to that of the control sample (PBK). Actual cohesiveness values for samples no. 1 and no. 7 were 0.18±0.02 and 0.18±0.01 respectively, where the predicted values were 0.17 and 0.19, respectively.

TPA adhesiveness

Adhesiveness (“stickiness”) is the work necessary to overcome the attractive forces between the surface of the food and the surface of other materials with which the food comes in contact (e.g. tongue, teeth, palate, etc). Its mathematical definition is: area under the load vs. distance curve, measured from where the cycle 1 first reaches zero load to where it ends. Generally speaking, lower adhesiveness is a desirable textural attribute of spreads. All tested samples had adhesiveness values lower than peanut butter (Table 2). The analysis of variance showed that the regression model was significant ($F$-value of 12.15, $R^2=0.8967$ and $p<0.0024$), indicating the validity of the equation to predict the response function. The equation was as follows:

$$\text{TPA Adhesiveness (mJ)} = 2 - 0.17X_1 - 0.32X_2 + 0.30X_1X_2 + 0.29X_1^2 + 0.36X_2^2 \quad [4]$$

Figure 1d shows that the adhesiveness had lower values at higher levels of stabilizer and hemp oil content. A linear effect of hemp oil content and quadratic effect of both
variables on the adhesiveness were observed. The results indicated that the interaction between two variables was not significant. In this case, the adhesiveness of the control sample (PBK) did not have a desirable value; we wanted our spread to be less sticky to the teeth than peanut butter, which was successfully achieved. In order to optimize the variables with the adhesiveness values lower than PBK, the target for the TPA adhesiveness model was minimized and the predicted model showed the best model fit for stabilizer content of 1.2% and hemp oil content of 20%. The response surface results were verified by comparing the experimental values with the predicted values. The predicted adhesiveness of the sample no. 7 was 4.08 mJ, whereas the actual value was 3.75±0.17 mJ.

**Correlation between product responses**

The correlation coefficients between product responses are presented in Table 4.

<table>
<thead>
<tr>
<th>Table 4. Correlation coefficients between product responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardness (g)</strong></td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td><strong>Hardness (g)</strong></td>
</tr>
<tr>
<td><strong>Cohesiveness</strong></td>
</tr>
<tr>
<td><strong>Adhesiveness (mJ)</strong></td>
</tr>
</tbody>
</table>

*Significant at p ≤ 0.001

Both texture attributes, cohesiveness and adhesiveness correlated negatively with the product hardness. There was a higher correlation observed between the cohesiveness and hardness ($R^2 = -0.82$) than between the adhesiveness and hardness ($R^2 = -0.72$). Hence, the softer product will have a better structure, but it will be stickier to the teeth. Cohesiveness and adhesiveness showed a high positive correlation ($R^2 = 0.96$). Hence, based on the results, the lower quantities of added hemp oil and stabilizer will produce softer spreads with higher consistency and elasticity, but they can be adhering to the teeth and mouth roof. However, as shown in this experiment, due to the lower adhesiveness values, the spreads would not be sticking to the teeth, to the degree the peanut butter does.

**Optimization of the responses**

In order to obtain a fat-based spread with the texture of a peanut butter and no oil separation on the surface, utilizing a by-product from the oil pressing process, the optimal level of two major component contents were determined based on the combination of responses. Multiple numerical optimizations (by the software) were carried out to determine an optimum level of independent variables with desirable responses.

The components’ content was optimized for the minimum values of hardness and adhesiveness, with a target for maximum values of cohesiveness, with a stability of the spreads similar to peanut butter. The majority of generated models explained adequately the variation of the responses with satisfactory $R^2$ values (minimum of $R^2 > 0.87$) and non-significant lack of fit. This indicated that most variations could be well explained by the quadratic models and can be considered adequate because the probability level of $F$
was $p < 0.05$, and mostly $p < 0.01$ and $p < 0.001$. The regression equations obtained in this study can be used to find optimum components content for the desired TPA parameters. The optimum conditions were 1.0-1.2% of added stabilizer and 20-40% of added hemp oil. Samples no. 1 (1.0 % stabilizer/40 % hemp oil content) and no. 7 (1.2 % stabilizer/20 % hemp oil content) were closest to the instrumental texture of the control sample (PBK).

**CONCLUSIONS**

This study demonstrates that all of the primary texture attributes, such as hardness, cohesiveness and adhesiveness of spreads made with naked pumpkin seed press-cake, can be well predicted using instrumental methods for texture analysis (TPA). Hardness or spreadability, among other texture attributes, such as adhesiveness and cohesiveness, is one of the most important factors in deciding overall acceptance of spreads, as it is for some other foods. Therefore, finding optimal levels of texture parameters based on the control sample (PBK) which had a desirable texture, except for the adhesiveness, should be very helpful in designing new fat-based spreads, without using a sensory panel. Instrumental TPA provided an effective screening technique, without employing sensory evaluation, to select formulations in an acceptable range with important textural characteristics to match those of a commercial peanut butter. RSM was a reliable and effective technique for analyzing effects of variables and their interactions to describe and predict the texture of the spreads. This study contributes to the basis of designing processes for pumpkin seed press-cake utilization, based on enhanced understanding of the usefulness of instrumental TPA in the prediction of the texture of fat-based spreads.

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ОПТИМИЗАЦИЈА ТЕКСТУРЕ МАСНОГ НАМАЗА НА БАЗИ ПОГАЧЕ СЕМЕНА УЉАНЕ ТИКВЕ ГОЛИЦЕ (Cucurbita pepo L.)

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Погача семена уљане тикве голице, нуспроизвод при производњи тиквиног уља пресовањем, је коришћена за припрему нове формулације намаза на бази уља који је сличан кикирики маслацу, како по изгледу тако и по текстури. У овом раду је коришћена метода одзивних површина да би се испытао утицај комерцијалног стабилизатора и хладно пресованог конопљиног уља додатог погачи уљане тикве голице на текстуру припремљених намаза употребом инструменталне методе анализе текстура.

Обе испитиване променљиве су имале значајан утицај на одабране одзиве у централно композитном двофакторском експерименталном дизајну на пет нивоа. Добијени су стабилни и чврсти намази без видљивог издавања уља на површини, који су имали изглед и текстуру сличну кикирики маслацу. У смислу примарних особина текстура као што су тврдоћа, кохезивност и адхезивност, одређене помоћу инструменталне анализе текстура, оптимална комбинација за производњу оваквог намаза је била уз додатак 1-1,2% стабилизатора и 20-40% конопљиног уља (у масној фази производа).

Кључне речи: масни намаз, погача семена тикве голице, инструментална анализи текстура, оптимизација, методологија одзивних површина

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