Viscosity and Textural Attributes of Reduced-fat Peanut Pastes
S.K. SINGH, M.E. CASTELL-PEREZ, AND R.G. MOREIRA

ABSTRACT: The viscosity and texture attributes of reduced-fat peanut pastes (more than 50% fat reduction) using combinations of protein-based Simplesse-500™ (S), starch-based PCR 352-1 (P), and water (W) were studied at 23°C. Viscosity data were obtained for the shear rate range of 0.067 s⁻¹ to 148.9 s⁻¹ using the Brookfield Viscometer HB-DVIII with spiral adapter. Results demonstrated that two formulations produced pastes with viscosity similar to the control (reduced-fat [30%] peanut butter): 54:5, 59.5, and 57.6 Pas at 38.2 s⁻¹, respectively. Sensory tests showed that these pastes were lighter in color, easier to spread, less firm and grainy that the control. Results suggest the potential for development of >50% reduced-fat peanut pastes.

Key Words: fat replacers, shear thinning, viscosity, spreadability, mouthfeel

Introduction

One of the greatest assets of peanut butter is flavor. The high protein and fat content render it especially suitable for combining with carbohydrate foods, and the flavor is compatible with sweet and carbonated drinks. Peanut butter has enormous use as a spread for bread and crackers: It is used in sandwiches, cookies, confectioneries, in flavoring foods, wafers, patties, bars, and other snacks. However, peanut butter has about 50% fat (75% calories from fat or 17 g of fat per 2 tablespoons) (Woodroof 1983).

A 1996 national survey revealed that 88% of the U.S. population (90% of women and 87% of men) consume low-fat, reduced-fat, or fat-free foods and beverages. Yet the question remains whether most consumers can adhere to a reduced-fat diet for the extended period required to realize any health benefits. Adherence may be improved with the availability ofpalatable low-fat foods (CCC 1996).

Development of reduced-fat peanut butter has been a great challenge for food technologists (O’Donnell 1993). Several procedures for preparation of low-calorie and reduced-fat peanut butter have been developed. A method for preparation of reduced-fat peanut butter produced a water-in-oil emulsion containing a continuous peanut butter oil phase, a protein complexing agent (to maintain consistency of the oil phase), and a discontinuous aqueous coagulated protein phase (to reduce the fat content of the peanut butter). The discontinuous phase contained a coagulated protein (to reduce the fat content of the peanut butter). The ground peanuts then separated from the supernatant oil layer, and the resulting peanut paste was reground. Maltodextrin and modified food starch were added to the paste (Franklin 1994). Quality of products was poor (Singh 1996).

Several low-fat peanut butter products are available at stores. However, the maximum fat reduction in these products is only 30% (12 g fat per 2 tablespoons) as the result of using a reduced percentage of peanuts in their formulations, which have been replaced by corn-syrup solids, maltodextrin, or soybean proteins (Singh 1996). Also, consumer acceptance of such products depends on their ability to spread on another material and has a direct relationship with viscosity and flow behavior (Kokini and Dickey 1982).

A review of the major industrial efforts under way to find appropriate substitutes for fats in food products describes 2 main approaches: (1) combinations of water with surface active lipids or nonlipids (such as modified carbohydrates or proteins) having emulsifying or high-swell gel properties, with lower food-energy values; and (2) noncaloric compounds with fat-like properties, but whose ester bonds are modified (O’Donnell 1993). The first approach has serious limitations: (1) It is difficult to achieve more than a 50% reduction in fat content, and (2) certain foods (for example, ice cream) are not the same as their full-fat counterparts when that much fat is removed.

The food-ingredient industries have developed a wide variety of low-calorie fat replacers. The largest number of fat replacers are carbohydrate-based. These ingredients are plant polysaccharides and include cellulose, gums, dextrins, fiber, maltodextrins, starches, and polydextrose (Matters 1998). When added to foods, fat replacers thicken and add bulk, thereby producing a mouthfeel similar to that provided by fat. Fat replacers also contribute emulsification and structural properties. Protein-based ingredients include egg white, skimmed milk or whey, and zein. Protein replacers contribute 1.3 to 4 kcal/g and have the biological value of the component amino acids (Matters 1998).

The main objective of this study was to formulate a >50% reduced-fat peanut paste with textural (sensory) and rheological (viscosity) characteristics similar to the traditional product. The specific objectives were: (1) to evaluate the effect of fat substitution on the rheological properties of reduced-fat peanut paste, and (2) to establish the optimum combination of moisture-fat replacers to produce an acceptable product (sensory textural attributes).

Results and Discussion

Rheological behavior

Research on peanut butter indicates the existence of a yield stress that directly relates to the spreadability of that product (Kokini and Dickie 1982). Therefore, the shear stress-shear rate data were fitted to a Herschel-Bulkley model (r² = 0.87),

\[ \sigma = K\dot{\gamma}^n + \sigma_0 \]  

(1)

where \( \sigma \) = shear stress (Pa), \( K \) = consistency coefficient (Pa sⁿ), \( n \) = flow-behavior index (dimensionless), \( \dot{\gamma} \) = shear rate (s⁻¹), and
Attributes of Reduced-fat Peanut Pastes

\( \sigma_0 = \text{yield stress (Pa)} \). However, the values of yield stress obtained from the log (\( \sigma - \sigma_0 \)) in contrast to log (\( \gamma \)) were so small (\( \sigma_0 = 0.0001 \text{ Pa} \)) that they were considered negligible in this study. These results may be due to the instrument setup used in this study, and further work must be undertaken using more sensitive instrumentation.

Since the objective of this study was to evaluate differences (if any) in the formulated pastes due to differences in composition (fat content) using simple rheological procedures, the rheological behavior of all formulated pastes was then described by the power-law equation (\( r^2 > 0.98 \), \( K \gamma^n \)), and the apparent viscosity, \( \eta_a (\text{Pa s}) \), was modeled as

\[
\eta_a = K\gamma^n-1
\]

Table 1 shows the flow-behavior parameters (\( n \) and \( K \)) for selected pastes plus the control. Only results for the room-temperature samples are presented in this article because the trend at refrigerated temperature was identical (Singh 1996).

Analysis of variance shows that there were significant (\( \alpha < 0.05 \)) differences in the values of \( n \) and \( K \) between treatments and control. The values of the flow-behavior index, \( n \), ranged from 0.46 to 0.52 (average of 0.49) in contrast to a value of 0.57 for the control. Fat reduction accentuates the degree of pseudoplasticity (shear thinning) in the formulated pastes (lower value of \( n \)). A shear-thinning fluid material should spread (flow) more easily at higher rates of shear than the control sample, and its effect on oral texture detected.

The values of the consistency coefficient, \( K \), ranged between 225.7 Pa s\(^n\) and 514.9 Pa s\(^n\) (average of 364.6 Pa s\(^n\)) in contrast to a value of 250.85 Pa s\(^n\) for the control. Addition of water (\( W \)) significantly (\( \alpha < 0.05 \)) decreased the consistency coefficient (value of \( K \)) of the formulated paste, while addition of \( S \) and \( P \) increased the consistency of the pastes. The effect of addition of \( P \) was more relevant when moisture content was high (Treatments #15, #18, and #24). These samples were also found to be firmer by the sensory evaluation panel.

Analysis of variance shows the main effect of the starch-based fat replacer to be 12.03%. \( P \) consists of 0.02-0.2 \( \mu \)-dia starch particles (malto-dextrin) that have the capacity to absorb water and render thickening of the paste, resulting in an increase in consistency. But its thickening effect is reduced when used with \( S \). This result suggests that there is some interaction taking place between \( S \), \( P \), and other ingredients. However, \( P \) has a greater effect on consistency than \( S \) (Table 1).

**Apparent viscosity**

There was a significant difference between treatments (\( \alpha < 0.05 \)) (Table 1). The effect of \( W \) was the highest as 76.56% of the variation in apparent viscosity due to concentration of ingredients. This model contributes 96.78% of the total effect. \( W \) had the highest effect (90.11%) followed by \( P \) (10.71%). \( \eta_a \) was modeled as

\[
\eta_a = K\gamma^n-1
\]

**Table 1—Effect of formulation on flow-behavior parameters (flow behavior index (n), consistency coefficient (K), and apparent viscosity (\( \eta_a \)) of x 50% reduced-fat peanut pastes**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>( S )</th>
<th>( W )</th>
<th>( P )</th>
<th>( n ) [( \mu )g]</th>
<th>( K [\text{Pa s}^n] )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>0.57( a )</td>
<td>250.85( a )</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>40</td>
<td>1.26</td>
<td>0.50( d )</td>
<td>334.80( h )</td>
</tr>
<tr>
<td>6</td>
<td>5</td>
<td>40</td>
<td>2.50</td>
<td>0.52( b )</td>
<td>377.53( h )</td>
</tr>
<tr>
<td>9</td>
<td>5</td>
<td>45</td>
<td>2.50</td>
<td>0.48( f )</td>
<td>329.54( h )</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>45</td>
<td>0.00</td>
<td>0.50( f )</td>
<td>508.89( j )</td>
</tr>
<tr>
<td>13</td>
<td>10</td>
<td>40</td>
<td>0.00</td>
<td>0.50( f )</td>
<td>225.74( i )</td>
</tr>
<tr>
<td>14</td>
<td>10</td>
<td>40</td>
<td>1.25</td>
<td>0.49( f )</td>
<td>390.90( m )</td>
</tr>
<tr>
<td>15</td>
<td>10</td>
<td>40</td>
<td>2.50</td>
<td>0.49( f )</td>
<td>514.91( a )</td>
</tr>
<tr>
<td>18</td>
<td>10</td>
<td>45</td>
<td>2.50</td>
<td>0.46( h )</td>
<td>415.22( d )</td>
</tr>
<tr>
<td>22</td>
<td>15</td>
<td>40</td>
<td>0.00</td>
<td>0.51( c )</td>
<td>286.96( b )</td>
</tr>
<tr>
<td>23</td>
<td>15</td>
<td>40</td>
<td>1.25</td>
<td>0.51( c )</td>
<td>383.91( b )</td>
</tr>
<tr>
<td>24</td>
<td>15</td>
<td>40</td>
<td>2.50</td>
<td>0.46( b )</td>
<td>476.76( c )</td>
</tr>
<tr>
<td>26</td>
<td>15</td>
<td>45</td>
<td>1.25</td>
<td>0.51( c )</td>
<td>227.99( c )</td>
</tr>
<tr>
<td>27</td>
<td>15</td>
<td>45</td>
<td>2.50</td>
<td>0.49( a )</td>
<td>266.82( c )</td>
</tr>
</tbody>
</table>

Reduced-Fat Roasted Peanut Powder (24% oil content) = 50 g
Corn-Syrup Solids = 2.50 g
Salt = 0.75 g
1\( S \) = whey-protein based, Simplesse\textsuperscript{TM}-500 (g)
2\( W \) = water (ml or %)
3\( P \) = starch-based PCR-352-1 (g)
4\( V \) viscosity calculated at 50 rpm (38.3 s \(^{-1} \)) using Brookfield HB DV-III+ viscometer data and paste spindle (#70) at room temperature (\( T = 23^\circ C \)).
Means are average of 3 replications
Means with same letter are not significantly different (\( \alpha = 0.05 \))
Means are average of 3 replications
Means with same letter are not significantly different (\( \alpha = 0.05 \))
MSE = 3.724011 (sum of mean square error)
MSD = 5.8059 (mean significant difference), df = 26
Critical value of Studentized Range for \( K \) = 5.2110
Critical value of Studentized Range for \( n \) = 0.0345

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From the ANOVA and regression analysis, 5 effects were found significant, and a model was developed to estimate the variation in apparent viscosity due to concentration of ingredients. This model contributes 96.78% of the total effect. \( W \) had the highest effect (90.11%) followed by \( P \). The regression equation for apparent viscosity at \( T = 38.3 \text{s}^{-1} \) is:

\[
\eta_a = 57.6 - 48.3 [W] + 7.3 [P] - 0.4 [P × S] + 0.5 [W]^2 + 0.2 [W × P × S]
\]

Equation 3 is only valid for the specific ranges of \( [W] \), \( [P] \), and \( [S] \) used in this study. Significant differences were observed with...
the pastes formulated using 40% [W] and 5.0 g [P], with a significant increase in apparent viscosity at lower shear rate values. Treatment #18 yielded a thicker paste. This result may be due to the higher concentration of [P] (2.5 g) (Table 1). Treatments #5 and #18 produced a paste with apparent viscosity similar to the control throughout the entire shear rate range.

Water is actually absorbed by the starch and protein molecules in food materials, and gelation takes place, thus adding to consistency. However, addition of extra amount of water hinders gelation, causing a decrease in apparent viscosity and “bad” consistency (Singh 1996). This result may be 1 of the reasons for the drastic decrease in viscosity when water content increased from 40 to 45 ml (Table 1). Another reason may be the fact that water itself behaves as a plasticizer (lubricant). Increasing the level of [S] from 5 g to 10 g in presence of [P] (1.25 g) increases viscosity from 54.5 to 61.3 Pa.s, which indicates that [P] requires more water than [S] to achieve the same paste consistency.

Analysis of variance shows that the effect due to [P] (12.02%) on apparent viscosity was higher than the effect of [S] (0.26%). Apparent viscosity of pastes increased as the amount of [P] increased, as it can be seen from Treatments #4, #5, and #6 (0.0, 1.25, and 2.5 g P) with 40 ml [W] and 5 g [S] with apparent viscosity values of 36.9, 54.5, and 70.8 Pa.s, respectively (Table 1). The effect of [P] is almost linear with respect to viscosity increase. The same trend was observed at higher [S] levels for all water contents. The above results suggest that Treatments #5 and #18 are the best formulations (in terms of apparent viscosity, thus flow behavior).

Sensory evaluation

The data of 3 replicates collected for treatments and control samples were reported as means (Table 2). The panel results are as follows:

**Color.** All formulated samples were rated lighter (tan) in color than the control sample (caramel) (12.31 on the 15-cm rating scale), with values ranging from 3.35 (Treatment #5) to 11.51 (Treatment #10). These differences in color were statistically significant (α < 0.05).

An increased amount of [S] (Treatments #5, #14, and #23) significantly increased the color scores (3.35, 6.97, and 9.02, respectively). The amount of [P] added also significantly increased the scores (3.35 and 4.61 for Treatments #5 and #6, with 1.25 g and 2.50 g P, respectively). This effect was more significant at higher levels of [S] (scores of 8.80, 9.02, and 10.38 for Treatments #22, #23, and #24, respectively). Pastes with higher moisture levels in the formulation were found to be lighter in color by the panelists.

**Oiliness.** All formulated samples were significantly more oily than the control (score of 3.09), with values ranging from 4.69 (Treatment #6) to 12.81 (Treatment #14). Comparing the scores for Treatments #5, #14, and #23, (5, 10, and 15 g S, respectively, with 40 ml [W] and 1.25 g [P], the oiliness ratings increased significantly from 11.10 (Treatment #5) to 12.81 (Treatment #14) and then significantly decreased to 9.45 (Treatment #23). A similar trend was observed when 2.50 g [P] was added (Treatments #6, #15, and #24), with scores changing significantly from 4.69, 9.28, and 5.51, respectively. This seems to indicate that 10 g [S] yielded pastes that were considered more oily, while addition of [P] had the opposite effect.

**Spreadability.** All the treatments yielded pastes that were significantly more spreadable than the control (score of 12.99), with values ranging from 1.83 (Treatment #18) to 11.39 (Treatment #10). The significance of this finding is not clear due to the lack of published results on reduced-fat peanut paste. However, a study observed that a good rating for spreadability of full-fat peanut butter should be between 4 and 6 on a 15-cm rating scale (Resurreccion 1988). Based on this, the formulated pastes from Treatments #5 and #22 appeared to yield the best pastes (scores of 4.66 and 6.49, respectively).

There was no significant difference among spreadability scores for pastes from Treatments #6, #15, and #26. This suggests that the amount of [S] did not affect the spreadability properties of the pastes at the specified formulation levels. However, the score for Treatment #24 (15 g S) was significantly higher (10.73), indicating that an increase from 10 to 15 g of the fat replacer decreased the spreadability of the paste at high levels of [P] (2.50 g). One reason may be the fact that [S], a milk-whey protein, is sticky in nature itself. The starch-based fat replacer [P] is not sticky, while it shows some slipperiness in nature, and in combination with [S], it does not affect viscosity but gives body to the product.

**Firmness.** Among the treatments, #10 yielded the paste that was firmer (score of 10.27), with a lower value of 2.34 for Treatment #18. Treatment #10 also yielded a paste with similar firmness characteristics to the control. This sample contained the less water in the formulation (35 ml) and no [P] added. Further increase in water content and amount of [P] (Treatments #14 and #15) significantly reduced firmness. This result could be due to the “diluting” effect of moisture and the water-fat replacer in-
teration. On the other hand, addition of [S] from 10 to 15 g signif-
icantly increases the firmness of the paste (Treatments #14 and #23), with scores of 3.26 and 8.35, respectively) at medium-

Adhesiveness. There was no significant difference (α < 0.05) within the treatments as well as among treatments and control. Score for the control sample was 13.12, and values for formulated samples ranged from 12.41 (Treatment #10) to 14.16 (Treatment #23) (Table 2).

Mouth coating. There was significant difference among treatments (α < 0.05) (Table 2). The control had the highest score for mouth coating (13.58), and values for the formulated samples ranged from 3.07 (Treatment #18) to 11.66 (Treatment #14). A rating of 9.0 has been considered desirable for full-fat peanut butter (Muego and others 1990; Muego and Resurreccion 1993). There were no significant differences among Treatments #5, #6, #14, and #15, which suggests that addition of selected fat replacers did not affect mouth-coating properties. Mouth-coating properties do not depend on any 1 factor but on the interaction effect of [S], [P], and water [W] content in the formulated samples. Increasing the amount of [P], [S], and [W] decreased the mouth-coating properties of the pastes, and the overall trend was that the less viscous samples also showed less mouth-coating properties, as expected (Resurreccion 1988; Muego and others 1990; Muego and Resurreccion 1993).

Graininess. The treatment means (Table 2) indicate that the control was significantly more grainy (score of 14.27) than the formulated samples, with values ranging from 0.83 (Treatment #26) to 2.00 (Treatment #6). In this study, all the formulated pastes were less grainy than the control.

Conclusions

HIGH-FAT REDUCTION (> 50%) PRODUCED PEANUT PASTES

With non-Newtonian, time-independent, and increased shear-thinning behavior when subject to steady shear flow than the control. In general, the formulated reduced-fat peanut pastes were lighter in color, easier to spread, and less firm and grainy than commercial reduced-fat (30% fat reduction) peanut butter. With the exception of color, these attributes were considered similar to the textural attributes of full-fat peanut butter by a trained sensory panel. Formulated pastes also showed similar adhesiveness and mouth-coating characteristics but were more oily than the control. Pastes from 2 treatments (#5 and #18) were recommended as the formulations to use to produce > 50% reduced-fat peanut paste with acceptable textural and rheological characteristics.

Materials and Methods

Peanuts

Shelled Spanish peanuts (The Clinton Williams Co., Madihll, Okla., U.S.A.) were stored at refrigeration temperature (7 ± 1 ºC) until further use when peanuts were allowed to reach room temperature.

Fat replacers

Two types of fat replacers were used in this study: (1) protein-based Simplesse-550 [S] (The Nutrasweet Co., Decatur, Ill., U.S.A.), made from whey protein concentrate; and (2) a microcrystalline cellulose PCR-352-1 [P] (FMC Corp., Philadelphia, Pa., U.S.A.). The 2 types were chosen for use in formulation based on preliminary tests for texture and viscosity characteristics that would best resemble the traditional peanut butter (Singh 1996).

Peanut paste manufacture

Two patented methods were modified to produce reduced-fat peanut paste (Izzo and Lieberman 1993; Franklin 1994). The procedure was as follows:

Roasting. Whole peanut kernels were roasted in an electrically heated wok pan (Westbend Co., Westbend, Wis., U.S.A.) with temperature control. Ceramic beads (1.5 mm dia) were heated with constant agitation until reaching a temperature of 160 ± 1 ºC. Pre-weighed peanuts were added to the beads (1:4 peanuts-to-ceramic beads ratio), and the mixture was covered with a lid for 50 min (Singh 1996). After roasting, peanuts were separated from the ceramic beads by sieving and cooled to room temperature. The roasted peanut kernels were blanched, skinned by hand, and then stored at 7 ± 1 ºC in Zip-lock polyethylene bags.

Oil extraction. A Carver Laboratory Hydraulic Press with “Carver Cage Equipment” Model 2094 (Carver Inc., Menomonee Falls, Wis., U.S.A.) with a plunger attachment was used to extract oil from the roasted peanuts. The ejector/base plug was placed on a collection pan. Two felt filter pads were inserted in the bottom of the cage, which was filled with 400 g of roasted peanuts (10 cm height). The filled cage was positioned under the plunger, and pressure applied (1.25 and 5.0 tons for 2.5 min and then 2.5 and 7.5 tons for 5 min each) for a total extraction time of 15 min. This procedure yielded the maximum amount of oil extracted (25.45% by weight). Oil content in the defatted peanuts was determined using the Soxhlet extraction method (Singh 1996).

Milling. The reduced-fat roasted peanuts (RFRP) were milled in a plate mill (Streb 4E, Streb Co., Philadelphia, Pa., U.S.A.) to obtain reduced-fat roasted peanut powder (RFRPP). Powder samples were then manually mixed, placed in airtight glass bottles, and stored at 7 ± 1 ºC. Samples were brought to room temperature before use.

Reduced-fat peanut paste. The treatments: Amounts of Simplesse-500 [S], water [W], PCR-352-1 [P], salt, and corn-syrup solids were selected on the basis of preliminary studies [6]. PCR-352-1 (0 to 2 g) was placed in an Omini Mixer cup with the distilled water (35-45 ml) and mixed at 6000 rpm for 1 min for complete dissolution at room temperature (23 ± 1 ºC). Then [S] was added to the mixture (5 to 15 g) and mixed at 2000 rpm for 1 min. After that, 50 g of RFRPP, 1.5 g of salt, and 5 g of corn-syrup solid (FRO-DEX 24-D) were added to the above mixture and mixed at 2000 rpm for 30 s, then mixed by spatula and again mixed at 2000 rpm for 30 s. The procedure was repeated 4 times to get a uniform paste that was then stored in airtight petri dishes at refrigeration temperature (7 ± 1 ºC) for sensory evaluation and immediately used for rheological studies.

Viscosity

Complete rheological studies on peanut butter have already been carefully carried out (Kokini and Dickey 1982; Campanella and Peleg 1987). This study will only determine flow behavior and viscosity of formulated pastes to determine the effect (if any) of fat reduction on their rheological properties as they may relate to textural and product-handling characteristics.

Rheological studies of the control sample (a commercially available peanut butter product, 30% fat reduction) and the formulated pastes were carried out using a Brookfield Rheom-
Sensory evaluation

Spectrum terminology for descriptive analysis of semisolid texture (oral texture of peanut butter), the questionnaires for an oral- and mechanical-texture panel, and intensity-scale values (0 to 15) for semisolid oral-texture attributes as described by Meilgaard and others (1991) were modified to develop the appropriate evaluation tools for this study. A 15-cm unstructured line rating scale with appropriate reference points was used to evaluate the samples. Five panelists (3 females and 2 males) from an age group of 25 to 40 years old were selected after a series of screening tests that examined sensory acuity, discriminatory ability, interest, attitude, and availability of the candidate.

The number of paste samples formulated in this study was reduced to 10 from the initial 27 treatments by the trained panel on the basis of appearance, color, and spreadability compared to commercial reduced-fat peanut butter (control). A randomized complete block design was used to evaluate the 10 samples (5 samples in each block). Blocks as well as samples within the block were randomized for each sensory evaluation session. The panel evaluation was conducted for 6 sessions, with 6 samples (5 formulated plus the control) being evaluated per session. Order of presentation for the samples was randomized among the panelists to eliminate bias. Color evaluation was conducted under white light with all panelists evaluating the same samples.

Pastes were prepared in advance and stored in the refrigerator. Four h prior to testing, the samples were brought to room temperature. Each panelist received a rating form, room-temperature distilled water (8 oz), 1 slice of white bread for each peanut-paste sample (25 g), a knife, napkin, and expectorate cup with lid. The texture for each sample was described and intensity indicated by placing a vertical line across the 15-cm horizontal line based on the reference standards.

Data analysis

The experimental design for rheological studies was a 3 factorial arranged in RCB design. Three replications were carried out, and the treatments were arranged in blocks. The 10 treatments for sensory evaluation were arranged in 2 blocks with 3 replicates randomly arranged in blocks. The viscosity and sensory data were analyzed using ANOVA and Tukey’s Studentized test for mean separation at significance level of α < 0.05. Trend analyses were conducted by contrast study to find the effect of independent variation on viscosity change. The rheological model was developed using regression analysis. The SAS software was used for statistical analysis (SAS 1990).

References


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