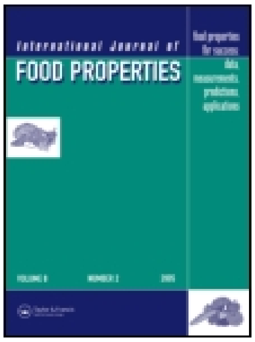

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EMULSION AND PASTING PROPERTIES OF RESISTANT STARCH WITH LOCUST BEAN GUM AND THEIR UTILIZATION IN LOW FAT COOKIE FORMULATIONS

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In this study, emulsion and pasting properties of resistant starch (RS) preparations with/without locust bean gum and their utilization in low fat cookies were investigated. The acid-hydrolysed corn starch sample was autoclaved, stored at 95°C for 0, 2, 3, and 4 days for formation of RS preparations I, II, III, and IV, respectively. RS preparations had significantly lower peak and breakdown and higher trough viscosities than hydrolysed starch. RS preparations with gum resulted in a cold thickening capacity. While native and hydrolysed starches had deteriorative effect on emulsion capacity and stability of the soy protein, RS preparations (with/without gum) did not have a deteriorative effect. Reduction of shortening caused significant decrease in spread ratios of control cookies with/without gum. However, utilization of RS preparations in low fat cookies caused significant increases.

Keywords: *Low fat cookie, Resistant starch, Locust bean gum, RVA, Emulsion properties.*

INTRODUCTION

Resistant starch (RS) is the starch fraction that is not digested in the small intestine but may be fermented in the colon. RS has been shown to have physiological benefits resembling soluble dietary fibers.[1–3] Fermentation of RS in the colon results in production of high concentration of short chain fatty acids,[4] which has been related to lowering the cancer risk.[5] Furthermore, RS containing food products were shown to lower plasma cholesterol and improve glucose tolerance.[6,7] RS contents in food range approximately between 0–4%. A higher amount of RS in the human diet is recommended due to its preventative and therapeutical health effects.[8] RS can be naturally present in foods or may be formed due to processing conditions.[9] The manufacture of resistant starch usually involves partial acid hydrolysis and hydrothermal treatments, retrogradation, extrusion and chemical modification.[6] Food applications of resistant starch are of interest to product developers and nutritionists mainly due to fiber-fortification and the potential physiological benefits, as well as unique technological properties. RS provides better appearance, texture, color, flavor, and mouthfeel than conventional fibres in cereal products.[6,10,11,12]

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Fat interacts with other ingredients to develop texture, mouthfeel and overall sensation of lubricity of food products.[13,14,15,16] However, high fat intake is associated with various health disorders such as obesity, cancer, high blood cholesterol, and coronary heart disease.[17] Due to this, there have been continued efforts to reduce the fat content in food products and replace it with various fat replacers. The most difficult part of reformulating with the fat substitutes is attaining the mouthfeel, texture, taste, and lubricity equivalent to that found in the conventional products. Carbohydrate based fat replacers form a gel-like matrix in the presence of substantial levels of water, resulting in lubricant and flow properties similar to those of fats.[18]

Food hydrocolloids are water-soluble, high molecular weight biopolymers that serve a variety of functions in food systems, such as increasing viscosity and creating gel-structures; control of crystallization and syneresis; the encapsulation of flavors; and improving texture and shelf-life.[19] Starches are known to participate in synergistic interactions with hydrocolloids.[20] It is generally accepted that addition of a hydrocolloid may influence the viscosity[21,22] and retrogradation rate of starch dispersions, as well as the syneresis of starch gels.[23] Since both ingredients are present in many food systems, their interaction has a strong impact on the rheology/texture of foods including them.[23,24] Starches and gums are often used together in food systems to provide proper texture, control moisture, and water mobility, improve overall product quality and stability, reduce costs, and facilitate processing.[25,26] Guar and locust bean gums, alginates, carrageenans, and xanthan gum are among the hydrocolloids most frequently employed as stabilizers.[26] Hydrocolloids have been shown to alter the gelatinization and retrogradation characteristics of starches.[27,28,29]

The objective of this study was to investigate the effect of locust bean gum on the emulsion and pasting properties of acid modified corn starch and resistant starch preparations. Furthermore, low fat cookies were formulated using the acid modified corn starch/resistant starch preparations with and without locust bean gum addition.

MATERIALS AND METHODS

Materials

Normal corn starch with an amylose content of around 25% from Cargill Inc. (Istanbul, Turkey) and locust bean gum from Incom Co. (Mersin, Turkey) were used in this study.

Acid Modification and Resistant Starch Formation

Corn starch was suspended in 6% HCl with a starch to acid ratio of 2:3 (w:v) and incubated at 40°C for 2.5 h. Optimum acid hydrolysis time was determined as 2.5 h in a previous study.[30] After the incubation period, the pH of the suspension was adjusted to 6 with 10% NaOH (w:v). Then the sample was washed three times with distilled water and centrifuged (Heraus Labofuge, Germany) at 1000 rpm for 5 min.[31] The washed sample was dried at 40°C and ground to pass through 212 μm sieve. For resistant starch formation, acid-modified starch sample was suspended in distilled water (1:10) and gelatinized at 85°C for 15 min. Then they were autoclaved at 121°C for 30 min and stored at 95°C for 2, 3, 4 days. They were dried at 50°C, ground and sieved. RS contents of the samples were determined by the enzymatic-gravimetric procedure.[32] Moisture contents of the samples were determined using the AACC Method No: 44-15A.[33]

Pasting Properties

Pasting properties of the samples were tested using a Rapid ViscoAnalyzer (RVA 4, Newport Scientific, Australia). A 4 g (14% moisture basis) starch sample and 25 g distilled water (adjusted to correct for sample moisture content) were placed in an aluminum sample canister. Locust bean gum was added at the ratio of 2.5 g gum/100 g starch. The RVA pasting curve was obtained by using a 30 min test: initial equilibrium at 30°C for 10 min, heating to 95°C over 6 min, holding at 95°C for 5 min, cooling to 50°C over 5 min and holding at 50°C for 4 min. The cold-paste viscosity, peak viscosity, trough, breakdown viscosity, and final viscosity values were evaluated with the data analysis software (Thermocline for Windows, Newport Scientific, Australia).

Functional Properties

Emulsion capacity and stability values were determined according to Ahmedna et al.[34] as modified by Bilgi and Celik [35] and the samples were prepared according to Abdul-Hamid and Luan[36] with some modifications. Five mL of 7% dispersion of the starch samples (prepared with 0.05% soy protein solution) were mixed with 5 mL of corn oil and homogenized at 23 500 rpm for 1 min by using a homogenizer (Art-Miccra D-8, Germany). Then it was centrifuged (Heraus Labofuge, Germany) at 2100 × g for 20 min. The ratio of the height of the emulsified phase to the height of total liquid was expressed as emulsion capacity (%). For the determination of emulsion stability, homogenized sample was incubated at 45°C for 30 min and then centrifuged at 2100 × g for 20 min. The ratio of the height of the emulsified phase to the height of total liquid was expressed as emulsion stability (%). In order to investigate the effect of locust bean gum on emulsion properties, the experiments were repeated by supplementing the starch samples with the gum at the ratio of 2.5 g gum/100g starch. Solubility and water binding values of the RS preparations were determined by the method of Singh and Singh.[37]

Cookie Production and Quality Evaluation

The cookies were prepared by AACC Method No: 10–54.[33] The baked cookies were left to cool before they were wrapped in aluminum foil and allowed to stand at room temperature until the analysis. For the production of low fat cookies, the amount of shortening in the cookie formulation was reduced by 40%, and this was compensated by the RS preparations. RS preparations were hydrated during the creaming stage at a starch: water ratio of 70:30. In order to investigate the effect of locust bean gum on cookie quality, the cookies were prepared by supplementing the starch samples with the gum at the ratio of 2.5 g gum/100g starch.

The quality parameters of the cookies were evaluated in terms of width (W), thickness (T), spread ratio (W/T), color (L*, a*, b*) and texture values. After cooling of the cookies for 30 min, width and thickness measurements of the cookie samples were taken by using a caliper. The color values (L*, a*, b*) were measured with a Minolta spectrophotometer (CM-3600d, Japan). Texture Analyser (TAPlus, Lloyd Instruments, UK) equipped with a three-point bending jig was used for texture analysis and the maximum force (N) required to break cookie sample was determined 24 h after the baking. The span between the supports was 40 mm.

Statistical Evaluation

Data were analyzed for variance using the MSTAT statistical package. When significant differences were found the LSD (Least Significant Difference) test was used to determine the differences among means.[38]

RESULTS AND DISCUSSION

The optimum hydrolysis time for the formation of resistant starch was determined as 2.5 h in a previous study.[30] Resistant starch contents of RS preparations I, II, III, IV formed by acid hydrolysis, autoclaving and storage at 95°C for 0, 2, 3, 4 days were 13.2%, 16.1%, 16.7% and 16.6 %, respectively. On the other hand, native starch and acid-modified starch samples did not contain any RS, as expected. Solubility and water binding values of the RS preparations were in the range of 2.60–3.18% and 229–254%, respectively.

Pasting Properties

RVA pasting properties of acid hydrolysed corn starch and resistant starch preparations with and without locust bean gum are given in Table 1 and Figs. 1 and 2. Significant decreases were observed in all of the RVA pasting properties due to 2.5 h hydrolysis, as expected. Gelatinized-autoclaved starch samples prepared with and without storage prior to drying (RS preparations I, II, III, and IV) had significantly lower peak viscosity values. However, they had higher trough viscosity and lower breakdown values as compared to those of the hydrolysed starch sample, indicating lower level of shear thinning (better hot

Table 1 RVA pasting properties of acid hydrolysed corn starch and resistant starch preparations with and without locust bean gum.[1,2]

Samples	Cold-paste viscosity (cP)	Peak viscosity (cP)	Trough viscosity (cP)	Breakdown (cP)	Final viscosity (cP)
Without gum					
Native corn starch	0	5886 a	2468 a	3418 a	5929 a
2.5 h hydrolysed starch	0	1221 b	129 e	1092 b	495 b
RS preparation I	0	477 c	406 b	71 c	714 b
RS preparation II	0	303 d	288 cd	15 c	566 b
RS preparation III	0	254 d	237 d	17 c	533 b
RS preparation IV	0	312 d	298 c	14 c	619 b
LSD ($p < 0.05$)	—	107.7	52.8	98.3	277.1
With gum					
Native corn starch	0 c	8755 a	3078 a	5677 a	6923 a
2.5 h hydrolysed starch	0 c	1916 b	144 c	1772 b	712 d
RS preparation I	27 b	1255 c	759 b	497 c	1148 b
RS preparation II	23 b	1015 d	873 b	142 d	998 c
RS preparation III	27 b	898 d	854 b	44 d	1026 bc
RS preparation IV	45 a	976 d	849 b	127 d	1078 bc
LSD ($p < 0.05$)	13.1	194.1	157.0	346.0	124.5

[1] Values followed by the same letter in the same column are not significantly different ($p < 0.05$).

[2] Means are based on duplicate analyses. RS preparation I: 2.5 h hydrolysed starch autoclaved and dried without storage. RS preparations II, III, IV: 2.5 h hydrolysed starch samples autoclaved and dried after 2, 3, and 4 days of storage at 95°C, respectively.

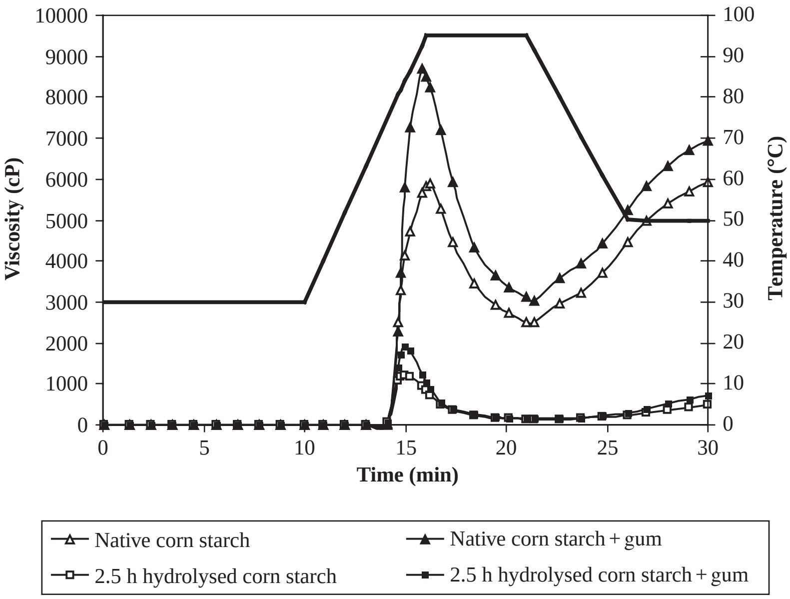

Figure 1 RVA pasting curves of native and acid hydrolysed corn starches with and without locust bean gum.

paste stability). Final viscosity values of the RS preparations were slightly higher than that of the hydrolysed starch sample, but the increases were not significant. Gum added samples had a similar trend as the samples without gum. However, gum addition caused increases in all of the viscosity values (Fig. 2.).

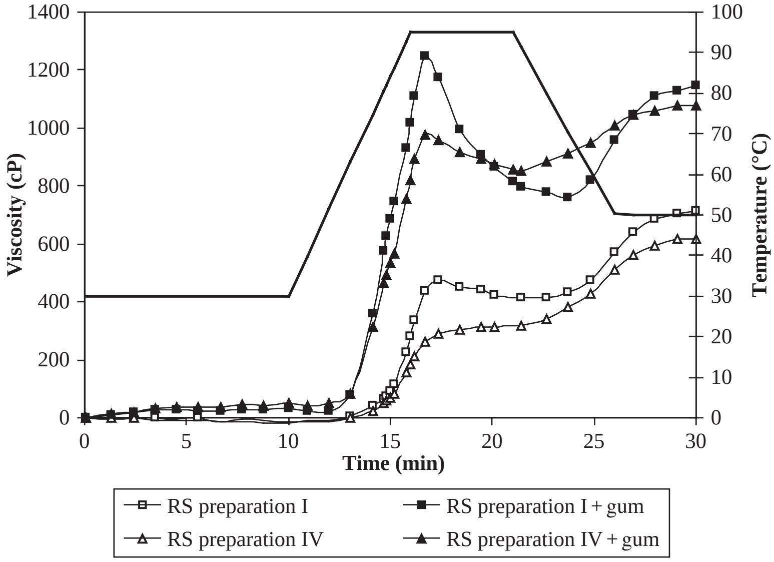

Figure 2 RVA pasting curves of selected resistant starch preparations with and without locust bean gum. RS preparation I: 2.5 h hydrolysed starch autoclaved and dried without storage. RS preparation IV: 2.5 h hydrolysed starch samples autoclaved and dried after 4 days of storage at 95°C.

A viscosity value higher than "0" at the initial stage of RVA curve (before heating) is referred to as cold-paste viscosity in the related literature.[39] Cold-paste viscosity was not observed for native and 2.5 h acid hydrolysed starch samples. Since, the starch is gelatinized prior to RS formation, it is expected to observe cold-paste viscosity. However, in the present study, such cold-paste viscosity values were not observed in the RVA curves of gelatinized-autoclaved starch samples prepared with and without storage prior to drying (RS preparations I, II, III, IV) and the viscosity values increased as the temperature increased (Fig. 2.). These results are in agreement with those of Becker et al.[40] The lack of cold-paste viscosity might be probably due to loose rearrangement of starch chains during drying, with a small number of H-bonds. This can be different from regular retrogradation of starch during RS formation. The loose rearrangement of starch chains in different parts of the structure might prevent water uptake at the initial stages of RVA test prior to heating. Later on, viscosity increases as a result of water uptake by the system, following H-bond disruption due to heating. Then a peak is formed. Although, the reason for the formation of this peak is different, its shape is similar to the one observed during starch gelatinization.[30] Cold-paste viscosity was observed in the gelatinized-autoclaved starch samples, prepared with and without storage prior to drying, after locust bean gum addition. RS preparation IV had the highest cold-paste viscosity ($p < 0.05$). The cold-paste viscosity/cold thickening capacity is an important property in various food and industrial applications. It might influence the functional properties such as emulsion capacity and stability as well as foaming properties.

Emulsifying Properties

Emulsifying properties of acid modified corn starch and resistant starch preparations with and without locust bean gum are given in Table 2. Proteins are commonly used as emulsion forming and stabilizing agents. On the other hand, starch can not produce emulsion by itself, but might effect emulsion properties.[41] Therefore, in the present study,

Table 2 Emulsifying properties of acid modified corn starch and resistant starch preparations with and without locust bean gum.[1,2]

	Without gum		With gum	
Samples	Emulsion capacity (%)	Emulsion stability (%)	Emulsion capacity (%)	Emulsion stability (%)
Soy protein (0.05%)	20.0 a	18.5 b	20.0 a	18.5 a
Native corn starch	5.6 c	9.0 d	4.3 c	7.2 c
2.5 h hydrolysed starch	10.3 b	13.5 c	12.6 b	13.4 b
RS preparation I	19.4 a	20.6 ab	19.0 a	19.6 a
RS preparation II	20.4 a	20.0 ab	18.2 a	18.9 a
RS preparation III	21.3 a	20.3 ab	18.5 a	16.8 ab
RS preparation IV	21.7 a	22.6 a	18.8 a	16.7 ab
LSD ($p < 0.05$)	2.78	2.61	3.93	3.49

[1] Values followed by the same letter in the same column are not significantly different ($p < 0.05$).

[2] Means are based on duplicate analyses. RS preparation I: 2.5 h hydrolysed starch autoclaved and dried without storage. RS preparations II, III, IV: 2.5 h hydrolysed starch samples autoclaved and dried after 2, 3, and 4 days of storage at 95°C, respectively.

effects of various starch preparations on the emulsifying properties of soy protein solutions were investigated. Emulsion capacity and emulsion stability values of soy protein solution (0.05%) were found to be 20.0% and 18.5%, respectively. Emulsion capacity and stability values of soy protein solution supplemented with the native corn starch and 2.5 h acid hydrolysed starch sample were significantly lower than those of the soy protein solution on its own. The results indicated that the native and acid modified starch samples affected the emulsion properties of the soy protein inversely. Native starch and 2.5 h acid hydrolysed starch samples are in granular form and do not have capacity for remaining at oil–water interface[41] and precipitated upon centrifugation applied after emulsion formation during the determination of emulsion capacity and stability values. The properties of the emulsions formed by the soy protein deteriorate probably due to precipitation of starch granules. Gelatinized-autoclaved starch samples, prepared with and without storage prior to drying, had significantly higher emulsion capacity and stability values, as compared to those of the native and acid hydrolysed starch samples. Emulsion capacity values of all RS preparations were not significantly different from that of soy protein. RS preparations I, II, and III did not significantly affect emulsion stability value of the soy protein. However, RS preparation IV had a significant improving effect on emulsion stability of the soy protein solution. Water binding values of the gelatinized-autoclaved starch samples, prepared with and without storage prior to drying, were relatively high (229–254%) as compared to those of native (96%) and 2.5 h acid hydrolyzed samples (104%).[30] Therefore, they tend to remain suspended in the emulsion and also at oil-water interface and precipitated to a lower extent upon centrifugation applied after emulsion formation, hence, not causing deterioration in the emulsion properties of soy protein solution. Furthermore, the solubility values of these samples were higher (2.60–3.18%) than those of native (0.17%) and 2.5 h acid hydrolyzed samples (0.34%).[30] The soluble portions of the gelatinized-autoclaved starch samples, prepared with and without storage prior to drying, might probably adsorb at emulsion droplet and might be fairly compatible at oil-water interface[41] due to their reduced average molecular weight during 2.5 h hydrolysis. Hence, they might have caused some improvements in the emulsion properties of soy protein solution.

Similar changes were also observed in emulsion capacity and stability values of the gum added samples. Soy protein solution and gum added RS preparations I, II, III, and IV were not statistically different in terms of emulsion capacity and stability values. While native and hydrolysed starches had deteriorative effect on emulsion capacity and stability of the soy protein, RS preparations (with/without gum) did not have a deteriorative effect.

Cookie Quality

Spread ratio and hardness values of low fat cookies with and without locust bean gum are given in Table 3. The spread ratio values of the cookies prepared with and without gum decreased significantly by 40% reduction of the shortening content. Among the cookies without gum, spread ratio values of the cookies including native corn starch or 2.5 h hydrolysed starch were not significantly different from that of the cookie sample with reduced shortening. However, a small but significant increase was observed in the spread ratio values of the cookies (without gum) in which the reduced shortening was replaced with the RS preparations. Cookies including RS preparation I, II, III, and IV were comparable in terms of the spread ratio values. In the gum added cookie samples, RS preparation I gave a cookie comparable to the ones including native corn starch or 2.5 h hydrolysed starch in terms of spread ratio. However, cookies including RS preparation II, III, and IV

Table 3 Spread ratio and hardness values of low fat cookies with and without locust bean gum.[1,2]

	Without gum		With gum	
Cookie samples	Spread ratio (W/T)	Hardness (N)	Spread ratio (W/T)	Hardness (N)
Control	6.48 a	45.0 b	6.35 a	50.3 a
40% of the shortening reduced	5.10 c	50.9 a	4.91 d	48.7 a
40% of the shortening replaced with:				
Native corn starch	5.02 c	37.5 c	5.05 c	36.4 b
2.5 h hydrolysed starch	5.02 c	37.2 c	5.02 c	37.8 b
RS preparation I	5.24 b	37.2 c	5.10 c	38.4 b
RS preparation II	5.21 b	37.0 c	5.25 b	39.1 b
RS preparation III	5.23 b	36.2 c	5.21 b	40.0 b
RS preparation IV	5.23 b	36.5 c	5.29 b	39.1 b
LSD ($p < 0.05$)	0.106	5.80	0.106	4.25

[1] Values followed by the same letter in the same column are not significantly different ($p < 0.05$).

[2] Means are based on triplicate analyses. RS preparation I: 2.5 h hydrolysed starch autoclaved and dried without storage. RS preparations II, III, IV: 2.5 h hydrolysed starch samples autoclaved and dried after 2, 3, and 4 days of storage at 95°C, respectively.

had significantly higher spread ratio values as compared to the samples in which the shortening was reduced.

The hardness results indicated that reduction in shortening content significantly increased the breaking strength of the cookies without gum. However, reduced shortening caused an insignificant decrease in the hardness value of the gum added control sample. Replacement of the reduced shortening with native corn starch, 2.5 h hydrolysed starch or RS preparations caused a significant reduction in the hardness values of the cookies with/without gum. However, their hardness values were comparable. The overall quality of the cookies did not seem to improve much when locust bean gum was included in the formulation. Sudha et al.[16] reported that the force required to break biscuits containing 70% less fat was almost three times more than that required to break the control biscuits. The spread of the biscuits reduced significantly when fat was reduced in the formulation. Biscuits containing normal fat level had a spread of 55.5 mm, which reduced to 50.5 mm when 70% fat was reduced in the formulation. Similarly, there was a significant increase in the thickness of these biscuits from 6.3 mm to 6.9 mm.

In the present study, reduction of the shortening (40%) did not significantly alter the L*, a*, and b* values of the cookies (Table 4). Furthermore, the changes in the color values of the cookies were not significant when 40% of the shortening was replaced with native corn starch, 2.5 h hydrolysed starch or the RS preparations.

CONCLUSION

In the present study, supplementation of RS preparations with gum resulted in a cold thickening capacity. The cold-paste viscosity is an important property in various food and industrial applications. It might influence the functional properties such as emulsion capacity and stability. RS preparations also had better hot paste stability. This might be desirable in certain food products in which a drastic viscosity decrease during prolonged cooking processes is not desired. Although native and acid hydrolysed starch samples

Table 4 Color values of the low fat cookies with and without locust bean gum.[1,2]

Cookie samples	Without gum L*	Without gum a*	Without gum b*	With gum L*	With gum a*	With gum b*
Control	64.9	7.02	22.9	63.6	7.94	23.2
40% of the shortening reduced	68.0	6.36	21.1	70.3	5.40	20.5
40% of the shortening replaced with:						
Native corn starch	72.1	4.87	20.7	70.2	5.75	21.9
2.5 h hydrolysed starch	73.2	4.51	20.2	70.8	5.43	21.6
RS preparation I	68.0	6.50	22.7	68.6	6.12	22.6
RS preparation II	69.8	5.72	21.8	69.3	5.89	22.1
RS preparation III	69.4	5.83	21.9	68.6	6.20	22.4
RS preparation IV	68.5	5.91	22.0	69.1	5.95	22.5
LSD ($p < 0.05$)	NS	NS	NS	NS	NS	NS

[1] Values followed by the same letter in the same column are not significantly different ($p < 0.05$).

[2] Means are based on triplicate analyses. RS preparation I: 2.5 h hydrolysed starch autoclaved and dried without storage. RS preparations II, III, IV: 2.5 h hydrolysed starch samples autoclaved and dried after 2, 3, and 4 days of storage at 95°C, respectively. NS: not significant.

caused a significant decrease on emulsion capacity and stability values of soy protein, RS preparations did not have a deteriorative effect on emulsion properties of soy protein. Addition of gum and RS preparations to cookie formulation caused an increase in spread ratio value of the reduced shortening cookie. The RS preparations obtained in the present study seem to be promising for the production of low fat cookies. Further studies are needed to investigate the functional properties of various RS preparation-gum blends and their effects on low fat cookie quality.

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