Food Structure

Volume 1 | Number 2 Article 11

1982

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FOOD MICROSTRUCTURE, Vol. 1 (1982), pp. 223-231
SEM Inc., AMF O'Hare (Chicago), IL 60666, U.S.A.

MORPHOLOGICAL AND TEXTURAL COMPARISONS OF SOYBEAN MOZZARELLA CHEESE ANALOGS PREPARED WITH DIFFERENT HYDROCOLLOIDS

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Abstract

The morphology and texture of mozzarella cheese analogs prepared from soy protein isolate, gelatin, fat and different hydrocolloids (gums) were evaluated and compared. The fracturability, hardness and adhesiveness of the cheese analog gels were found to be proportionally related to the amount of fat and gelatin, and concentration and viscosity of gums. However, the stretchability of the cheese analog progels was not controlled by the viscosity of gums, but by the amount of gum and gelatin in the formulation. Fat content affected the fracturability and hardness, but did not have a significant effect on the other textural parameters or stretchability. This physical relationship enabled the preparation of cheese analogs with a broad range of fat contents. Microstructural studies indicated that gums with a lower viscosity formed a uniform and delicate gel network. Gums with a higher viscosity tended to form clumps in the gel network which might retard the alignment of molecules in the progel state and hence, adversely affect the stretching properties of the analog.

Initial paper received March 4, 1982.
Final manuscript received September 9, 1982.
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KEY WORDS: Soybeans, Mozzarella Cheese Analogs, Hydrocolloids, Stretchability, Texture Profile Analysis.

Introduction

The development of imitation mozzarella cheese products has progressed rapidly. Most of these products are made from caseinate, a milk protein derivative, which currently is imported and hence the price is expected to remain high. Therefore, it would be advantageous to use several novel, less expensive proteins in the formulation -- such as soybean or peanut proteins -- to replace the caseinate (Taranto and Yang, 1981; Ramamurti et al., 1964; Hannigan, 1979).

Previous reports (Taranto and Yang, 1981; Yang and Taranto, 1982) detailed the development of a mozzarella cheese analog prepared from soy protein, gelatin, fat and gum arabic. These analogs exhibited a typical cheese texture at room temperature. When heated, the analogs melted and stretched in a manner similar to that of natural low moisture-part skim mozzarella cheese.

When used at a concentration of 40% (w/v; 40 g. gum dispersed in 100 ml water), gum arabic induced a pseudoplastic flow behavior in the progel. The analog progel stretchability was similar to that found in melted mozzarella cheese (Taranto and Yang, 1981; Yang and Taranto, 1982). The high solids content of the analog -- composed of gum arabic, gelatin and soy isolate -- was found to induce a "bundle" pattern in the stretched progel similar to natural mozzarella. However, gum arabic used at a concentration of 40% (w/v) is not only costly but induces a tackiness on the surface of the cheese analog gel. Therefore, the use of other gums and hydrocolloids for the manufacture of cheese analogs was investigated. The results of this investigation are presented here.

Materials and Methods

Raw Materials

Soy protein isolate, Promine-D, was purchased at the start of this research from Central Soya Co. (Fort Wayne, IN). However, since that time, Central Soya has sold the soy isolate business to Archer Daniels Midland (Decatur, IL). A product, Ardex D, similar to Promine D is now being manufactured and sold by Archer Daniels Midland Co. Type B gelatin (128 bloom) was obtained from Baker Chemical Co.

(Phillipsburg, N.J.). A food grade mixture of powdered xanthan gum-locust bean gum-guar gum (XLG) was obtained from Kelco Co. (Rahway, N.J.) and a powdered guar gum (Jaguar A-40-F) was obtained from Celanese Plastics & Specialities Co. (Louisville, KY). Partially hydrogenated shortening made from coconut oil (Hydro-100) was obtained from Durkee Industrial Foods Group (Chicago, IL).

Sample Preparation and Rheological Evaluations

All samples were prepared and evaluated according to Taranto and Yang (1981) and Yang and Taranto (1982). Details of the sample preparation are given in the two referenced papers.

Textural properties such as fracturability, hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness of the gel were evaluated using the Instron Universal Testing Machine. Stretchability of the progel is measured with the Weissenberg test (Taranto and Yang, 1981). The progel was the molten or melted form of the cheese analog.

The melting quality test described by Kosikowski (1978) was used in conjunction with other rheological evaluations to investigate the differences among samples prepared with different gums. Melting quality is defined as the amount of radial expansion of a sample disc of known weight and dimensions after heating in an oven for a specified time and temperature. These rheological properties were correlated with microstructural observations.

Sample Preparation for Scanning Electron Microscopy (SEM)

All samples were prepared for SEM according to Taranto and Yang (1981). Samples were fixed, frozen in a liquid nitrogen slush, freeze dried, fat-extracted with chloroform and dry fractured. Samples were then mounted on SEM stubs, coated with gold and examined with a JEOL-JSM-U3 scanning electron microscope operated at 10 kV with a 200 μm aperture and a 13 mm working distance at a 40° tilt.

Statistical Analysis

The F-test procedure (one way analysis of variance) of Steel and Torrie (1960) with a 5% level of significance was used to analyze all data. Multiple comparison of means was performed using Tukey's Q statistic (Steel and Torrie, 1960).

Effect of Gums

Table 1 shows the viscosities of those gums used in this study. Gums such as guar, locust bean, xanthan and XLG form extremely viscous solutions at low concentrations as compared to gum arabic. It is easy to prepare solutions containing up to 40% (w/v) of gum arabic at 25°C and induce a significant thickening effect. The high solids solution is responsible for the excellent stabilizing and emulsifying properties of gum arabic when it is incorporated with a large amount of water-insoluble materials. The use of gum arabic at concentrations up to 40% (w/v) was required to develop a stretchable cheese analog (Yang and Taranto, 1982). However, since soy protein is also an excellent emulsifier, an investigation was initiated into the feasibility of using higher amounts of soy protein as a solids enhancer and a gum system with viscosity similar to gum arabic but at a much lower concentration (such as 0.5-1%).

XLG was chosen primarily because of the synergistic increase in viscosity that results from the mixture of gums and also because of its ability to form a thermoreversible and highly cohesive gel as the colloid concentration is increased. Guar gum was also studied because of its extremely

Table 1:
The viscosities (centipoise) of several gums at different concentrations

% (W/V)	Gum Arabic[1]	Guar Gum[1]	Locust Bean Gum[1]	Xanthan Gum[2]	XLG[3]
0.5	-	1,389	20	300	380
1.0	-	3,025	59	1,000	1,400
5.0	7	510,000	121,000	-	(gel)
30	200	-	-	-	-
40	936	-	-	-	-
50	4,163	-	-	-	-

[1]Glicksman, 1962
[2]Rocks, 1971
[3]Kelco Company

Table 2:
Formulations for soybean mozzarella cheese analogs.[1]

Sample Number	Gum, (g) (%)[2]	Gelatin (g) (%)	Soy Protein (g) (%)	Fat (g) (%)	Water, (g.) (%)
1	0.5 XLG (0.28)	20 (11.1)	40 (22.2)	20 (11.1)	100 (55.4)
2	1 XLG (0.55)	20 (11.0)	40 (22.1)	20 (11.0)	100 (55.2)
3	1 XLG (0.55)	30 (16.6)	30 (16.6)	20 (11.0)	100 (55.2)
4	1 XLG (0.50)	30 (14.9)	30 (14.9)	40 (19.9)	100 (49.8)
5	1 guar (0.55)	30 (16.6)	30 (16.6)	20 (11.0)	100 (55.2)
6	40 gum arabic (19.0)	40 (19.0)	20 (9.5)	10 (4.8)	100 (47.6)
7	40 gum arabic (17.4)	40 (17.4)	40 (17.4)	10 (4.3)	100 (43.5)
C	commercial natural mozzarella cheese (low moisture part-skim) with 17.4% fat and 46.5% moisture.				

[1]Samples were prepared according to the procedure described by Yang and Taranto (1982).
[2]As-is percentage based on total formula weight.

high viscosity at low concentrations(Table 1).

Effect of Gelatin and Soy Protein

Both gelatin and soy protein form thermoreversible gels at a certain concentration and temperature range. Although they are not stretchable in the progel state, they may have a synergistic effect on the progel stretchability in the presence of gums. Hence, different concentrations of these two proteins were studied (Table 2).

Effect of Fat

Fat was found to enhance the hardness of the cheese analog gel as well as the mouthfeel and heat meltability (Yang and Taranto, 1982). Therefore, we investigated the effect of fat incorporation on the texture, stretchability and melting quality using mixtures in which the solids content was reduced by replacing the 40% (w/v) gum arabic with 1% (w/v) of other gums (Table 2).

Results and Discussion

Composition data on samples made from different gums in addition to a commercial mozzarella cheese are listed in Table 2. Results of the Instron texture profile analysis (TPA), Weissenberg test, melting quality of these samples and several effects of the key ingredients are listed in Tables 3-6. Morphological comparisons are illustrated in Figures 1-8.

Effect of Gums

Samples prepared with 0.5 g. XLG (sample 1 in Table 2) and 1 g. XLG (sample 2 in Table 2) were compared with samples prepared with 40 g. gum arabic (samples 6 and 7 in Table 2). Although a 1% (w/v) XLG solution had a similar viscosity to a 40% (w/v) gum arabic solution (Table 1), cheese analog samples prepared with 40 g. gum arabic had

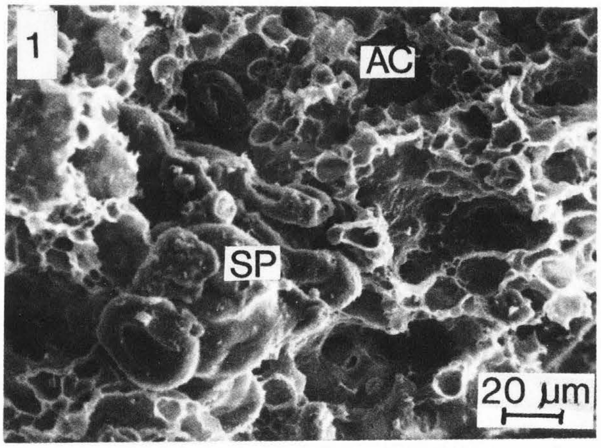

Figure 1 - Scanning electron micrograph of mozzarella cheese analog prepared from 40% gum arabic, 10% fat, 40% gelatin, and 20% soy isolate (Sample 6 in Table 2). Note the soy protein and gum particles (SP). AC-air cell.

Table 3:
Objective evaluations of samples made with XLG or gum arabic.[1]

Sample[2]	Fract. (kg)	Hard. (kg)	Adhes. (kgxcm)	Cohes.	Spring. (cm)	Gumm. (kg)	Chew. (kgxcm)	Stret. (cm)	Melting quality
1	0.68 ± 0.01^{b}	0.77 ± 0.01^{c}	0.18 ± 0.01^{b}	0.51 ± 0.01^{a}	1.53 ± 0.01^{a}	0.40 ± 0.02^{c}	0.60 ± 0.02^{c}	0^{c} 0	1.54 ± 0.02^{c}
2	0.58 ± 0.02^{b}	0.69 ± 0.02^{c}	0.20 ± 0.02^{b}	0.51 ± 0.01^{a}	1.53 ± 0.00^{a}	0.35 ± 0.01^{c}	0.54 ± 0.02^{c}	0.55 ± 0.05^{b}	1.74 ± 0.06^{b}
6	1.12 ± 0.03^{a}	1.12 ± 0.01^{b}	0.16 ± 0.03^{b}	0.50 ± 0.01^{a}	1.56 ± 0.01^{a}	0.56 ± 0.02^{b}	0.87 ± 0.03^{b}	0.58 ± 0.04^{b}	2.15 ± 0.04^{b}
7	0.98 ± 0.02^{a}	1.30 ± 0.03^{a}	0.28 ± 0.01^{a}	0.55 ± 0.01^{a}	1.58 ± 0.01^{a}	0.72 ± 0.01^{a}	1.13 ± 0.03^{a}	1.44 ± 0.01^{a}	1.60 ± 0.03^{a}

[1]Each value is a mean ± S.D. (n=4). Means in the same column with different letters are significantly different (p=0.05).
[2]Samples described in Table 2; samples 6 and 7 were external controls.

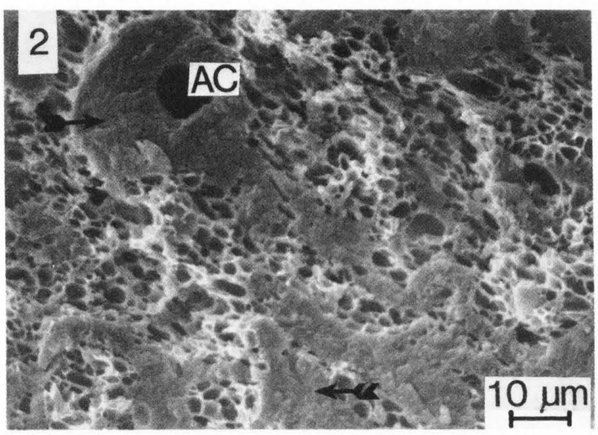

Figure 2 - Scanning electron micrograph of mozzarella cheese analog prepared from 0.5% XLG, 20% fat, 20% gelatin, and 40% soy isolate (sample 1 in Table 2). Note the protein "chunks" (indicated by the arrows). AC-air cell.

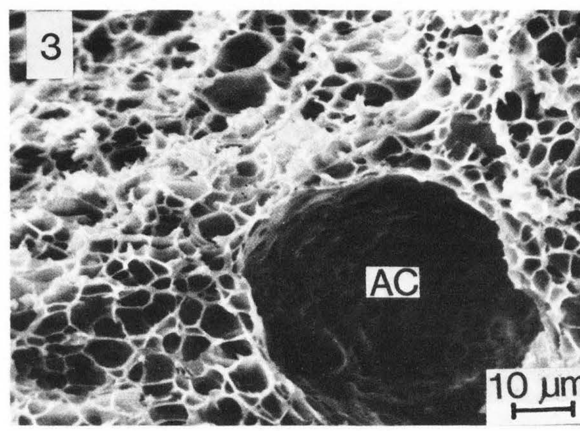

Figure 3 - Scanning electron micrograph of mozzarella cheese analog prepared from 1% XLG, 20% fat, 20% gelatin, and 40% soy isolate (sample 2 in Table 2). Note that there are no "chunks". AC-air cell.

significantly higher values for the fracturability, hardness, gumminess and chewiness (Table 3). This could be attributed to the higher solids content of gum and gelatin in samples 6 and 7 compared to that in samples 1 and 2 (Table 2).

The amounts of fat and soy protein isolate in the gum arabic samples were lower than those in the XLG sample (Table 2). Therefore, one would have expected higher TPA values for the XLG samples. Samples prepared with 0.5 g. and 1 g. XLG had similar TPA values (Table 3). SEM micrographs revealed that samples prepared with gum arabic exhibited some large gum particles with adhering soy protein (Figure 1). This was due to the slight salting-out effect with gelatin and gum arabic. These exuded gum arabic-soy protein particles are believed to be the cause of the tackiness on the surface of the cheese analog. Samples prepared with XLG (Figures 2 and 3) showed no visible gum particles. The gel surfaces were not tacky. The 0.5 g. XLG product (sample 1 in Table 2) exhibited numerous soy protein "chunks" in the gel matrix (Figure 2). No structure of this nature was observed in the 1 g. XLG product (sample 2 in Table 2; Figure 3).

It is theorized that the protein chunks in the 0.5 g. XLG product resulted from an

Table 4:
Objective evaluations of samples made with different gums.[1]

Sample[2]	Fract. (kg)	Hard. (kg)	Adhes. (kgxcm)	Cohes.	Spring. (cm)	Gumm. (kg)	Chew. (kgxcm)	Stret. (cm)	Melting quality
3	1.10±[b] 0.04	1.11±[c] 0.02	0.20±[c] 0.02	0.42±[b] 0.01	1.54±[a] 0.01	0.47±[c] 0.01	0.72±[c] 0.02	1.07±[b] 0.03	2.66±[a] 0.08
5	1.34±[a] 0.09	1.49±[a] 0.04	0.36±[a] 0.04	0.50±[a] 0.03	1.53±[a] 0.00	0.74±[a] 0.04	1.13±[a] 0.05	0[d]	2.06±[b] 0.20
6	1.12±[b] 0.03	1.12±[c] 0.01	0.16±[c] 0.03	0.50±[a] 0.01	1.56±[a] 0.01	0.56±[b] 0.02	0.87±[b] 0.03	0.57±[c] 0.04	2.15±[b] 0.04
7	0.98±[b] 0.02	1.30±[b] 0.03	0.28±[b] 0.01	0.55±[a] 0.01	1.58±[a] 0.01	0.72±[a] 0.01	1.13±[a] 0.03	1.44±[a] 0.01	1.60±[c] 0.03
C	0.90±[b] 0.07	1.15±[c] 0.01	0.38±[a] 0.01	0.49±[a] 0.03	1.52±[a] 0.02	0.60±[b] 0.04	0.86±[b] 0.04	1.10+[b] 0.01	2.49±[a] 0.05

[1]Each value is a mean ± S.D. (n=4). Means in the same column with different letters are significantly different (p=0.05).
[2]Samples described in Table 2; samples 6, 7 and C were external controls.

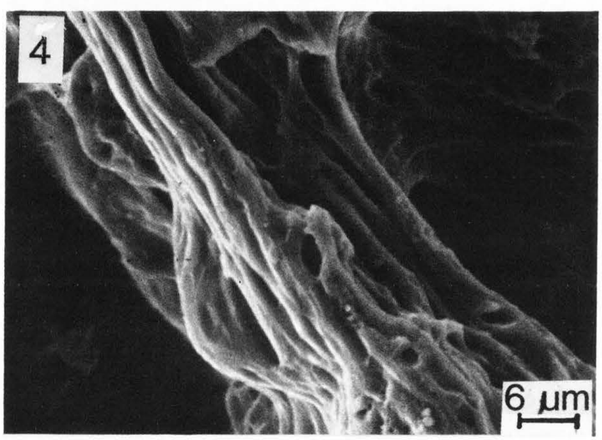

Figure 4 - Scanning electron micrograph of mozzarella cheese analog prepared from 1% XLG, 20% fat, 30% gelatin, and 30% soy isolate (sample 3 in Table 2). This micrograph was prepared from the sample in the stretched state, note the clear, fiber-type alignment in the stretched bundle.

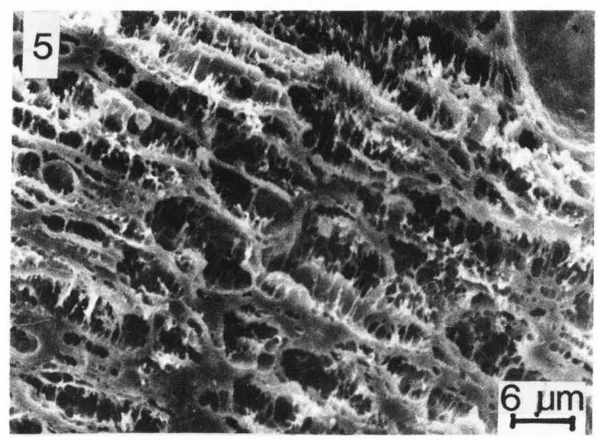

Figure 5 - Scanning electron micrograph of natural mozzarella cheese (low moisture part-skim). This micrograph was prepared from sample in the stretched state. Note the clear, fiber-type alignment in the stretched bundle.

insufficient amount of XLG to assist the soy protein in forming a honeycombed gel network with gelatin. The absence of chunks in the 1 g. XLG product (Figure 3) supports this explanation.

The condensed areas in the protein matrix of the 0.5 g. XLG product formed a slightly (though not statistically significant, Table 3) harder gel compared to the 1 g. XLG product. These condensed areas also prevented the alignment of the molecules during stretching and therefore, the Weissenberg test indicated a zero stretchability for the 0.5 g. XLG product (Table 3).

The morphology of the 1 g. XLG analog (sample 3 in Table 2) in the melted and stretched state is shown in Figure 4. The fibrous elements are formed into a large bundle approximately 20 µm in width. The structural features of the melted and stretched natural low moisture-part skim

Table 5:
Objective evaluations of samples made with different levels of gelatin and soy isolate.[1]

Sample[2]	Fract. (kg)	Hard. (kg)	Adhes. (kgxcm)	Cohes.	Spring. (cm)	Gumm. (kg)	Chew. (kgxcm)	Stret. (cm)	Melting quality
2	0.58 ± 0.02^{b}	0.69 ± 0.02^{b}	0.20 ± 0.02^{b}	0.51 ± 0.01^{a}	1.53 ± 0.00^{a}	0.35 ± 0.01^{c}	0.54 ± 0.02^{c}	0.55 ± 0.05^{b}	1.74 ± 0.06^{b}
3	1.10 ± 0.04^{a}	1.11 ± 0.02^{a}	0.20 ± 0.01^{b}	0.42 ± 0.01^{b}	1.54 ± 0.01^{a}	0.47 ± 0.02^{b}	0.72 ± 0.02^{b}	1.07 ± 0.03^{a}	2.66 ± 0.08^{a}
C	0.90 ± 0.07^{c}	1.15 ± 0.01^{a}	0.38 ± 0.01^{a}	0.49 ± 0.03^{a}	1.52 ± 0.02^{a}	0.60 ± 0.04^{a}	0.86 ± 0.04^{a}	1.10 ± 0.01^{a}	2.49 ± 0.05^{a}

[1]Each value is a mean ± S.D. (n=4). Means in the same column with different letters are significantly different (p=0.05).
[2]Samples described in Table 2; sample C was an external control.

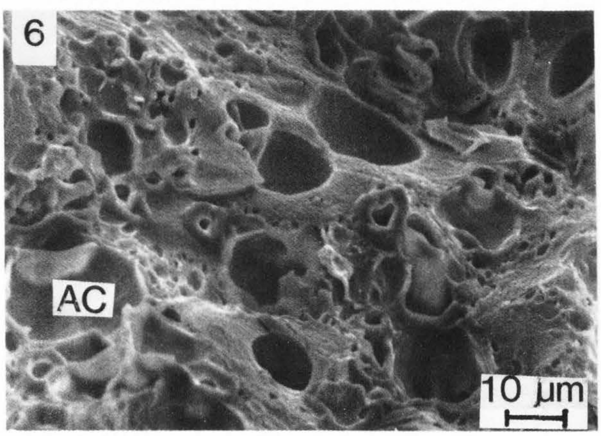

Figure 6 - Scanning electron micrograph of mozzarella cheese analog prepared from 1% guar gum, 20% fat, 30% gelatin, and 30% soy isolate (Sample 5 in Table 2). Note that a non-uniform honeycombed protein network is formed. AC-air cell.

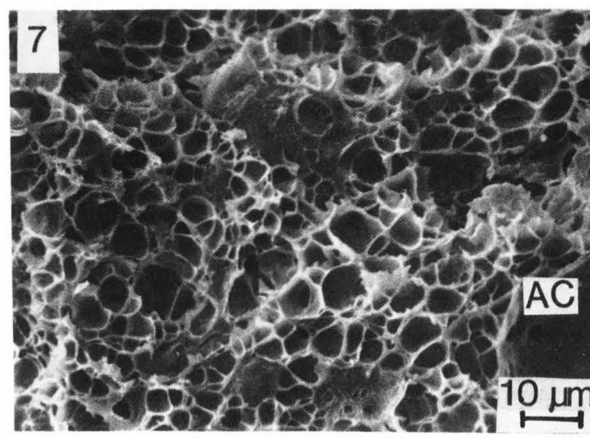

Figure 7 - Scanning electron micrograph of mozzarella cheese analog prepared from 1% XLG, 20% fat, 30% gelatin, and 30% soy isolate (Sample 3 in Table 2). Note the uniform, honeycombed protein network. AC-air cell.

mozzarella cheese are shown in Figure 5. There is an alignment of the fibrous elements with the fibers ranging from 0.5-6 µm in width. The stretched protein matrix shows numerous small voids which are separated by thin membranes (Figure 5). There was no significant difference in the stretchability between the 1 g. XLG analog (sample 3 in Table 2) and the natural mozzarella cheese (Table 4). Therefore, it appears that the formation and alignment of fibrous elements in the melted and stretched product is required for the analog to exhibit a stretchability equal to that of natural mozzarella cheese.

A 1% (w/v) guar gum solution has a viscosity about triple and double that of 40% (w/v) gum arabic and 1% (w/v) XLG solutions, respectively (Table 1). Analogs prepared with 1 g. guar gum (sample 5 in Table 2) had significantly higher values for fracturability and hardness than the analogs prepared with 1 g. XLG (sample 3 in Table 2) or commercial mozzarella cheese (Table 4). Adhesiveness of sample 5 (guar) was the highest among the samples prepared with different gums and was comparable to that of the commercial mozzarella sample (Table 4). Cohesiveness showed no significant difference except for the lower value of the 1 g. XLG analog (sample 3) (Table 4).

There was no detectable stretchability in

Table 6:
Objective evaluations of samples made with different fat contents.[1]

Sample[2]	Fract. (kg)	Hard. (kg)	Adhes. (kgxcm)	Cohes.	Spring. (cm)	Gumm. (kg)	Chew. (kgxcm)	Stret. (cm)	Melting quality
3	1.10±[b] 0.04	1.11±[b] 0.02	0.20±[b] 0.02	0.42±[a] 0.01	1.54±[a] 0.01	0.47±[b] 0.01	0.72±[b] 0.02	1.07±[a] 0.03	2.66±[a] 0.08
4	1.24±[a] 0.06	1.25±[a] 0.05	0.23±[b] 0.03	0.46±[a] 0.01	1.55±[a] 0.01	0.57±[a] 0.01	0.88±[a] 0.02	0.88±[b] 0.08	2.28±[b] 0.03
C	0.90±[b] 0.07	1.15±[b] 0.01	0.38±[a] 0.01	0.49±[a] 0.03	1.52±[a] 0.02	0.60±[a] 0.04	0.86±[a] 0.04	1.10±[a] 0.01	2.49±[a] 0.05

[1]Each value is a mean ± S.D. (n=4). Means in the same column with different letters are significantly different (p=0.05).
[2]Samples described in Table 2; sample C was an external control.

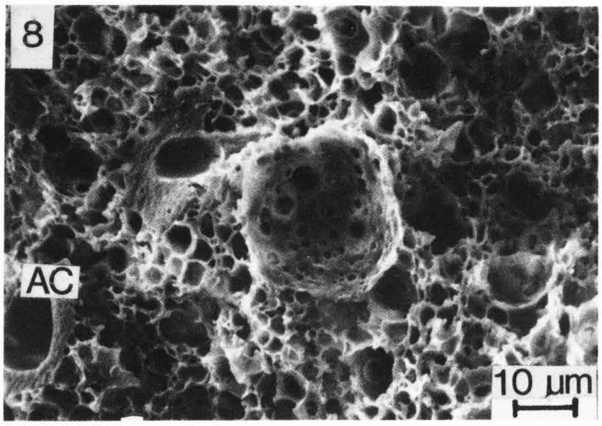

Figure 8 - Scanning electron micrograph of mozzarella cheese analog prepared from 1% XLG, 40% fat, 30% gelatin, and 30% soy isolate (Sample 4 in Table 2). Note that the size of the network voids is much smaller and the protein matrix is denser than in sample 3 (Figure 7). AC-air cell.

the 1 g. guar gum analog (sample 5, Table 4). The highly viscous guar gum tended to bind the proteins (soy and gelatin) into a dense matrix (Figure 6). There is a non-uniform honeycombed protein network. The air cells are numerous and variable in size (Figure 6). These structural features result in a much less flexible structure. The cheese analog made from 1 g. XLG with the same levels of soy protein, gelatin, fat and water (sample 3 in Table 2) exhibits a uniform, honeycombed protein matrix (Figure 7). This honeycombed matrix reforms into fibrous bundles when melted and stretched (Figure 4). This analog (sample 3) exhibits a stretchability equal to that of commercial mozzarella cheese (Table 4). The very dense protein matrix of the 1 g. guar analog (sample 5, Figure 6) is similar to the matrix seen in the 0.5 g. XLG analog (sample 1, Figure 2). Neither of these two samples had a stretchability that could be measured with the Weissenberg test.

The condensed protein matrix, in some manner, must prevent the formation and alignment of the fibrous elements when the analogs are melted and stretched. Without the formation of the fibrous bundles, the product will not exhibit the stretching and stringing characteristics of melted mozzarella cheese.

Effect of Gelatin and Soy Protein

Cheese analog samples 2 and 3 each contained the same amount of XLG and fat solids (Table 2). Sample 3 contained equal portions of gelatin and soy protein, whereas sample 2 contained gelatin and soy protein in a 1:2 ratio (Table 2). The TPA results indicated that sample 3, which had TPA values similar to the commercial mozzarella cheese, had almost twice the fracturability, hardness and stretchability as sample 2 (Table 5). This clearly indicates that gelatin contributed to both the gel texture and progel stretchability. The higher thermoreversible character of a gelatin gel (compared to a soy protein gel) enhanced the melting quality of sample 3 (Table 5). No distinct structural difference was detected between sample 2 (Figure 3) and sample 3 (Figure 7). The rigidity of the resultant gels appears to be dependent upon the concentration ratio of gelatin and soy protein when all other ingredients are held at a constant level.

Effect of Fat

Increasing the amount of fat while holding the level of other ingredients constant (sample 3 and 4 in Table 2) was found to significantly increase the fracturability and hardness of the XLG cheese analog (Table 6). The stretchability and melting quality of the analog were significantly decreased at higher fat levels (Table 6). The increase in hardness is due to the reinforcement effect of the additional fat in the gel system (Stainsby, 1977; Yang and Taranto, 1982)

The XLG analog prepared with a higher fat level (sample 4 in Table 2) is shown in Figure 8. The additional fat appears to have disrupted the uniformity of the honeycombed protein matrix (Figure 8). The size of the network voids has been reduced compared to the XLG analog with a lower fat content (sample 3 in Table 2; Figure 7). This decrease in size of the voids resulted in a denser protein network (a greater amount of solids per unit volume). This increase in density resulted in a higher gel resistance (rigidity) and lower stretchability. These data are in agreement with Yamano et al., (1981) who concluded that fat delayed soy protein gelation which resulted in a fine and hard gel structure.

Conclusions

Cheese analogs prepared with XLG were found to be the most similar to natural low moisture-part skim mozzarella cheese. In particular, sample 3 (Table 2) had the best match with mozzarella cheese in both the gel and progel states. Most important was that the XLG analogs were not tacky on the gel surface compared to the very tacky surface of the gum arabic analogs. The concentration ratio of gelatin and soy protein was found to significantly affect the gel and progel characteristics. Cheese analogs made with an equal proportion of gelatin and soy protein (sample 3 in Table 2) were found to have the best match with the TPA values and stretchability of mozzarella cheese.

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DISCUSSION WITH REVIEWERS

D. N. Holcomb: In the introduction you cite the (price) advantage of using "less expensive proteins... such as soybean..." The formulations shown in Table 2 rely heavily on gelatin. Is it a "less expensive" protein?

Authors: The current price for soy protein isolate is about $1.10/pound and gelatin about $2.15/pound. Refinement of our formulation to reduce the amount of gelatin is necessary to reduce the overall ingredient cost. We have studied a few other gelling agents, but none have performed as well as gelatin.

D.N. Holcomb: What are the organoleptic qualities of these products? Do taste panels agree that sample 3 is the most similar to natural mozzarella cheese?

Authors: The analogs as we prepare them have a very bland flavor. At this time, we have not run any formal sensory panels to compare products. We concluded that sample 3 was the most similar to mozzarella cheese based on our morphological and textural data.

K. Saio: Would you please explain what structural features of melted and stretched cheese are associated with "fiber alignment?"

Authors: When our cheese analog and natural mozzarella cheese is melted and stretched, the protein matrix in both products is elongated into large parallel fibrils. In the case of our cheese analog, these fibrils are interlaced in a rope-like fashion. In the natural mozzarella cheese, the fibrils appear to be crosslinked by a network of fine fibrils. In both cases, the fiber allignment we refer to is the parallel array of the large (coarse) fibrils.

W. J. Wolf: How did you ascertain that the large particles in the gum arabic containing analog (Figure 1) were gum arabic and that the adhering material was soy protein?

Although you attribute tackiness on the surface of the analog to the "gel particles" did you actually observe such particles on unfractured surfaces?
Authors: The large particles and adhering material were differentiated on the basis of their size and morphology. The morphology of the adhering material closely parallels the characteristics of soy protein particles reported by A. Hermansson (J. Amer. Oil Chemists Soc. 56: 275, 1979). We did not observe the "gel particles" on unfractured surfaces.

W. J. Wolf: What is the basis for attributing a "salting out" effect to gelatin and gum arabic in regard to the "adhering soy protein" on the large particles?
Authors: We believe this effect is due to a competition for the limited water available during the heat treatment phase of the analog manufacturing procedure. The soy proteins do not appear to effectively compete with the gelatin and gum arabic for the limited hydration water.

M. Kalab: Which polysaccharides in the various gums are responsible for the high viscosities of their solutions?
Authors: The viscosity of the various gum solutions is due to the structural features and molecular weight distribution of their respective polymers. We refer you to the textbook entitled: "Industrial Gums - Polysaccharides and their Derivatives," R. L. Whistler, Ed., Academic Press, 1959, for further details.

M. Kalab: Was the microstructure of gelatin and soy protein mixtures studied in the absence of gums? If yes, how did non-stretchable structures differ from the stretchable ones made with the gums?
Authors: No, we did not study the microstructure of gelatin/soy protein gels in the absence of gums. We did study the textural properties of such systems. A cheese analog can be made from gelatin and soy protein without gums. However, an excess of gelatin is required for the system to exhibit a texture which simulates a natural cheese. The system will melt when heated, but it is not stretchable.

D. A. Froehlich: Even though all formulations for the soybean mozzarella cheese analogs included 100 g. water, the final moisture content of the cheeses would have covered quite a wide range (approximately 43 to 55%). Was any consideration given to the effect of moisture content of cheeses to the TPA values?
Authors: Moisture content is indeed an important factor in TPA evaluations. In these experiments, we tried to keep the moisture content of the analogs prepared with the same ingredients constant (see samples 1, 2, 3 in Table 2). Except for sample 7 (Table 2), all the remaining analogs ranged between 48 to 55%. This range of moisture content was taken into account in the initial design of our experiment. Our initial data indicated a minimal effect on the TPA values over this range of moisture. We have recently completed a more detailed study on the effect of moisture content on the cheese analog TPA values. These data will be discussed in our next paper.