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Effect of Anionic Gums on the Texture of Pickled Frankfurters

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ABSTRACT

The addition of the anionic gums, xanthan and carrageenan, stabilized the texture of frankfurter emulsions against acid deterioration at 37°C in vinegar pickle. The proteins collagen, casein, and gluten, and the gums guar, arabic, and locust bean had no effect. The cationic gum, chitosan, formed an acid-stable gel but the gel would not hold the emulsion. The process of acid deterioration had an initial period of firming of the gel texture. Shear (rupture) and elasticity did not show a corresponding initial increase. Subsequent deteriorative changes were less in the emulsions with xanthan gum than in any of the other emulsions. The gum gel is formed at the expense of the protein-fat structure, probably through a gum-protein interaction.

INTRODUCTION

SHELF-STABLE MEAT PRODUCTS conserve energy in that they do not require refrigeration. They may be produced either by lowering the water activity through drying and/or salt addition, or by lowering the pH through fermentation or pickling. Products preserved by pickling in vinegar do not require removal of water and thus may be preserved at the initial moisture level, a quality which is important to the texture of comminuted or emulsified meat products. While pickled meat products are on the market, at room temperatures and especially during warm weather they tend to become mushy (Kosmin, 1976). This consideration led to testing the stability of emulsion-type products, specifically frankfurters, pickled in vinegar. At refrigerator temperatures of 3°C, the frankfurter gels were stable in the range pH 3–4, but at room temperature or higher (37°C), the resilient texture deteriorated and the frankfurters became mushy. The addition of gels or binders was suggested, but an examination of the literature showed that most binders and gels are unstable below pH 4.0, with the exception of xanthan gum (Jeanes et al., 1961). This gum, produced by *Xanthomonas campestris* fermentation, is stable down to pH 1. We therefore studied the effect of the addition of xanthan and other gums and protein binders on the stability of frankfurters pickled in vinegar.

MATERIALS & METHODS

Frankfurter production

The production of the frankfurters was described in a previous paper (Fox et al., 1982). For this study, frankfurters were also made without nitrite to determine if nitrite had any effect on stability of the frankfurters in pickle.

Gums and binders

Choosing appropriate gums and binders is something of an art (Hodge and Osman, 1976) requiring the testing of a number of different compounds. The compounds tested were: (1) sodium caseinate, the principal ingredient in nonfat dried milk frequently used as a binder in meat emulsions (Smith et al., 1973; Lauck, 1975; Rongey and Bratzler, 1966; Pearson et al., 1965); (2) gluten, which produces a stable gel in flour doughs and has been shown to bind meat pieces (Siegel et al., 1979); (3) collagen; (4) locust bean and guar gums, neutral seed gums that are little affected by heat processing acids, salts, or proteins (Hodge and Osman, 1976), all of which are common conditions or components of meat emulsion products; (5) gum arabic, because it has emulsifying properties; (6) xanthan gum, an acid-stable, anionic gum that is also salt and heat-stable (Jeanes et al., 1961; Rocks, 1971); (7) carrageenan, which like xanthan gum is anionic and binds to proteins; and (8) chitosan, a cationic gum derived from crustacean shells, our sample from crab shells. The guar, arabic, locust bean, and xanthan gums were food grade, the gift of the Meer Corporation, courtesy of Mr. John Tinker. The chitosan (lot 1761) was the gift of the Kypro Company, courtesy of Dr. Sidney Cantor. For purposes of comparison, the compounds were added at the level of 0.5% of the weight of the emulsion.

The various gums and proteins were added in various manners and times to determine the most efficacious procedure. Because of time and space limitations, it was necessary to group the experiments in sets of 4–6 batches to insure direct comparability. This also enabled us to assess the effects of normal processing variability, to which end a control and xanthan gum batch was included in each set. In the first set of frankfurters, the xanthan gum and the gluten were combined with ca 200 ml of water and the resulting gel added prior to the addition of the fat. In the second set, the gums and sodium caseinate were premixed with the spices prior to addition of the latter. In the third set (xanthan concentration series), the gum was dry-mixed with the spices before addition. In the fourth set (time of addition), portions of the xanthan gum were mixed with 200 ml of water and added to separate emulsions at 0.5 min (with the spices), 2.5 min after beginning the chop (before fat addtion), and at 6 min after the emulsion had reached 10°C (after fat addition). In the fifth and sixth sets, the various gums were added at 2.5 min by sprinkling them on the surface of the developing emulsion as it moved under the bowl cover.

Pickling

Twenty frankfurters from each batch were placed in 2-qt Mason jars and covered with 500 ml of 5% acid vinegar. As samples were withdrawn, the vinegar was replenished to keep the frankfurters covered. Jars of the pickled frankfurters were stored at 3°C and 37°C. The last was chosen to simulate relatively warm climatic conditions.

Raw and cooked emulsion tests

Stability of the raw emulsion was measured by heating a centrifuged portion of the raw emulsion and measuring the volume of fat and water released during cooking (Meyer et al., 1964).

Stability of the cooked emulsion was determined by submerging a frankfurter in boiling water for 10 min and recording the weight loss (or gain) (Whiting et al., 1981).

Processing loss was measured by weighing chains of linked frankfurters before and after cooking/smoking.

Texture characteristics

The rheological techniques used in this study are described in a previous publication (Fox et al., 1983). While penetration of a 1/4″ pin into the emulsion gave the most relevant results, the measurements of Warner-Bratzler Shear, maximum compressive force, decompression/compression, and multiple compression ratios yielded further information about the textural properties. The results of all five measurements are reported herein.

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Statistical analysis

The statistical significance of the results was determined by paired variate analysis or Duncan's multiple range test (Steel and Torrie, 1960).

Definitions

P, maximum force exerted during pin penetration; W-B, maximum force of Warner-Bratzler shear; CF, maximum compressive force; D/C, ratio of work of decompression to work of compression of samples, first cycle; MC, ratio of CF of fifth compressive cycle to that of the first.

RESULTS

OF ALL THE ADDITIVES STUDIED, only xanthan and carrageenan gums had any significant ($p < 0.001$) effect on the properties of the frankfurters. The properties of, and changes in, the frankfurters were the same for both gums; the effect of the other additives were the same as the controls. With slight set-to-set variations, all of the sets showed the same textural properties. Therefore, the results given for any one set hold true for all sets unless otherwise noted, and the results for the controls apply for the frankfurters with all additives other than xanthan and carrageenan gums.

Table 1—Emulsion stability and cook losses of frankfurters with various added gums and proteins[a]

Description	Process loss %	Meyer test, ml	Cook test, %
Set 1			
Control	7.1	—	−0.14
Xanthan	8.7	—	+0.12
Gluten	6.9	—	−0.98
Average	7.17 ± 0.78		
Set 2			
Control	13.9	0.90	−1.58
Xanthan	12.1	0.00	+1.12
Casein	11.3	1.28	−1.81
Guar	10.9	1.70	−4.28
Arabic	12.7	0.28	−5.66
Average	12.18 ± 1.19		
Set 3			
Control	10.8	1.23	+0.11
Xanthan 0.5%	10.3	0.00	+1.06
Xanthan 1.0%	8.0	0.00	+9.03
Xanthan 1.5%	11.3	0.00	+4.87
Average	10.10 ± 1.46		
Set 4			
Gum added; with spice	11.0	0.00	+1.95
before fat	10.1	0.00	+0.99
after fat	10.4	0.00	+3.21
Average	10.50 ± 0.46		
Set 5			
No NO_2	9.68	1.47	−0.71
Control	8.01	1.33	−0.57
Xanthan	6.70	0.00	+1.05
Locust bean	4.98	0.31	−0.49
X/LB[b]	7.65	0.00	+0.94
Average	7.23 ± 1.42		
Set 6			
Control	9.08	2.13	−2.74
Xanthan	8.04	0.00	+0.11
Carrageenan	7.75	1.13	−2.61
Collagen	7.07	1.00	−2.66
Chitosan	5.56	—	−41.7
No nitrite	10.22	2.90	−1.54
Average	7.95 ± 1.61		

[a] Sets weighted avg % = 8.21 ± 2.47%. Batch variation. s_{pooled} = ±1.15%.
[b] Xanthan and locust bean gum mix, 0.25% each in emulsion.

Change in acidity

One day in brine was sufficient to lower the pH of the outside surface from 6.2 to 4.8, while the pH of the core dropped to 5.4. After 2–3 days, the pH of both the core and surface of the frankfurters was within 0.2 unit of the ultimate pH of ca 4.3. If samples were removed, vinegar was added to keep the frankfurters covered with pickle, resulting in a slow continual drop from pH 4.3 to between pH 3.8–4.0 over the subsequent 3–4 wk of storage. There was no appreciable variation in the pH values between any of the sets or individual batches within the sets, and the decrease in pH was similar in both hot and cold vinegar pickle.

Emulsion characteristics

The variation in processing loss was about equally divided between batch and processing variation (Table 1). The weighted set deviation was ±2.47% and was a function of both batch and processing variations. The pooled standard deviation of the half of the set variations. The processing losses ranged from 6.9–13.9%, but none of the additives, including xanthan gum, had any significant effect on the loss.

The Meyer test (Table 1) is a dry cooking loss test, with a zero loss factor representing a highly retentive emulsion. Total liquid (fat and water) loss of the controls ranged from 0.9–2.13%. None of the other additives had any significant effect on reducing the loss, but xanthan gum completely eliminated liquid loss.

Because the cook test was carried out in boiling water, the cooked emulsions could have either lost or gained water. The controls and test batches without xanthan lost moisture, but the frankfurters with xanthan gum increased in weight during cooking. In set 3, increasing the percentage of xanthan from 0.5 to 1.0% increased water uptake from 1 to 9% with severe swelling and splitting in the 1.0% samples. Water uptake was probably even higher in the 1.5% xanthan samples, but these samples swelled and split so badly that there was extensive fat loss and emulsion

Table 2—Maximum force values (P) in grams for penetration measurements on freshly prepared frankfurters and after storage in vinegar for 3–3.5 wk at 3 and 37°C[a]

(1) Sample	(2) Set	Force in grams (3) Fresh	(4) 3°	(5) 37°
Control	2	512^{f*}	345^{k}	80^{tu}
	5	482^{ef}	470^{qr}	106^{u}
	6	426^{bc}	331^{k}	32^{s}
No NO_2	5	501^{f}	432^{pq}	84^{tu}
	6	$455^{c\text{-}e}$	$362^{k\text{-}n}$	75^{t}
Sodium caseinate	2	410^{b}	356^{km}	110^{u}
Collagen	6	432^{bc}	327^{k}	64^{t}
Guar	2	347^{a}	271^{j}	117^{u}
Arabic	2	413^{b}	337^{k}	117^{u}
Locust bean	5	481^{ef}	403^{np}	68^{t}
Xanthan	2	414^{b}	434^{pq}	216^{v}
	5	$442^{b\text{-}d}$	551^{r}	222^{v}
	6	342^{a}	433^{pq}	184^{v}
X/LB[b]	5	469^{de}	495^{r}	257^{w}
Carrageenan	6	428^{bc}	548^{r}	224^{v}
Chitosan	6	$457^{c\text{-}e}$	$393^{m\text{-}p}$	211^{v}

[a] Superscripts indicate groups of values not significantly different from each other.
[b] Xanthan and locust bean gum mix, 0.25% each in emulsion.

breakdown. The unusual feature of the water-holding property of xanthan gum was that although it increased water-retaining ability in both cook tests, the loss of water during processing was the same for the xanthan gum samples as for all the others.

Effects of the various gums and proteins

Table 2 is a summary of the P values for all of the additives studied, except gluten which was not tested. Although the Duncan's multiple range test (Steel and Torrie, 1960) indicated that there were significant subgroupings in the "fresh" values, there did not seem to be any relationship between these groupings and the additives. When the data was analyzed by sets, the samples of the fifth set were significantly firmer ($p < 0.05$) for both the fresh and the 3°C samples. (Because of the high variability in the 37°C samples the comparison could not be made.). Upon examination of the various factors involved in the frankfurter production, it was found that the frankfurters of set 5 had 11.2% beef fat as compared with 5.2% and 5.4% beef fat in sets 2 and 6, respectively. The observation is in accord with previous observations that the harder the fat, the stiffer the gel in the finished product (Baker et al., 1969; Lee et al., 1981). During cold storage (3°C) in vinegar, the gels with xanthan and carrageenan showed increased resistance to penetration, while all the other gels showed a decrease. When the frankfurters were pickled in vinegar at 37°C, the samples with the ionic gums—anionic xanthan and carrageenan and cationic chitosan—showed an average decrease in the P value of 49% of the initial values compared to 81% for the other gums and controls. It is necessary, therefore, for the gum to have a charge for textural stabilization to take place. However, even though the positively charged gum chitosan formed an acid-stable gel, the resulting gel would not hold the emulsion, losing most of the fat and shrinking badly when cooked (Table 1).

Storage stability

Fig. 1 shows the changes that occur with time in the maximum force (W-B) exerted during Warner-Bratzler shear measurements of the control and xanthan gum frankfurters of set 2. The curves for the frankfurters with casein, guar, and arabic gums were statistically the same as those for the control. While there was some loss of textural quality in the controls and the samples stored at 3°C, neither the addition of gum nor the pickling made any significant difference. When the pickled frankfurters were stored at 37°C (CH, XH), the frankfurters with xanthan gum showed a significantly higher shear force ($p < 0.02$) than did the controls after 21 days of storage. The difference was not great, since the control required 334g of force for cleavage, while the frankfurters with xanthan gum required 504g. However, the force required to shear the whole frankfurter was primarily the force required to shear the skin (Huang and Robertson, 1977), and it showed much less deterioration than did the interior gel (Fox et al., 1983).

The results of the penetration measurements of the control and xanthan gum frankfurters of set 2 as a function of time are shown in Fig. 2. There were two differences between the penetration and Warner-Bratzler shear results. Whereas the W-B values began decreasing immediately upon storage in pickle, the P values first increased 20–30%, then began to decrease. The second difference was that the deterioration in the control sample at 37°C was relatively much greater in the penetration measurements than it was in the W-B shear measurements; that is, the deterioration in the texture of the gel was greater than that of the skin. This difference was obvious in the aged samples in that even after the interior of the frankfurters had become soft, almost to the point of loss of dimensional stability, the frankfurters still had a relativeyly firm skin. Frankfurters with xanthan gum showed significantly ($p < 0.01$) less deterioration.

Compression

The maximum compressive force (CF) measurements from the compression studies showed the same rise and fall in firmness as did the penetration measurements. At 3 days the various samples increased an average of 15% from initial values ranging from 350–400 g/cm^2. The CF values for the 3°C samples then slowly decreased to about their initial values after 21 days of storage. The CF of the frankfurters gels containing xanthan or carrageenan gums stored at 37°C decreased to 60–70% of their initial values, while the CF of all the other frankfurters stored at 37°C decreased to 10–15% of their initial values.

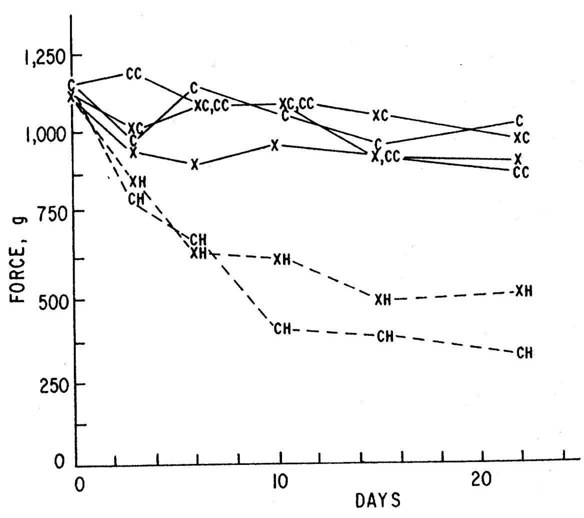

Fig. 1—Maximum force (W-B) exerted during Warner-Bratzler shear of whole frankfurters stored in casings at 3°C and in vinegar at 3°C and 37°C (set 2). C, control in casing; CC, control in 3° vinegar; CH, control in 37° vinegar; X, xanthan in casing; XC, xanthan in 3° vinegar; XH, xanthan in 37° vinegar.

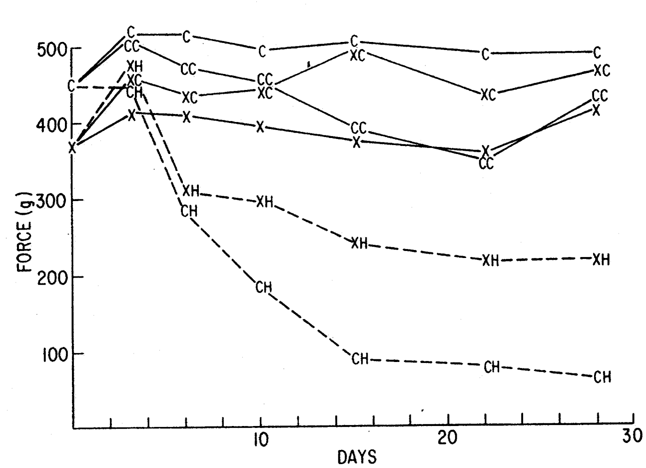

Fig. 2—Force (P) required to penetrate gels of frankfurters stored in casings at 3°C and in vinegar at 3°C and 37°C (set 2). C, control in casing; CC, control in 3° vinegar; CH, control in 37° vinegar; X, xanthan in casing; XC, xanthan in 3° vinegar; XH, xanthan in 37° vinegar.

The decompression/compression (D/C) and multiple compression (MC) ratios are both measurements of the elasticity of the gels. The first was a measure of a rapidly deteriorating elastic factor, while the second measured both an elastic factor with a slower rate of breakdown and a recovery of elasticity. While elasticity has been shown not to correlate with sensory properties of frankfurters (Quinn et al., 1979; Voisey et al., 1975), it was important to the recovery of shape after distortion during handling and packaging. As occurred with Warner-Bratzler shear, the processes of deterioration in elasticity began immediately upon storage in pickle, but the magnitude of the change was different for the D/C and MC measurements. The D/C values for the control frankfurters decreased to 8% of their initial values, but the MC values decreased to only 80%. The corresponding figures for the frankfurters with xanthan or carrageenan gums were 64% (D/C) and 87% (MC). The greater loss in the D/C values over the MC may be due to greater distortion in the D/C measurements. The D/C values measured an energy recovery after severe physical distortion of the samples, as evidenced by both rupture and flow of the samples which was considerable in the warm aged samples. In contrast, after the initial compression cycle, subsequent compression cycles did not exceed the rupture point of the samples. Decreases in subsequent compressive force maxima reflected a slower plastic flow as well as a recovery of elasticity during the release phase of the cycle.

Xanthan gum addition

The effects of xanthan gum addition on all measurements are summarized in Fig. 3 as percentages of the initial values. Little deterioration took place in pickle at 3°C, with a slight overall improvement in some of the properties of the xanthan gum frankfurters. The advantage of adding xanthan gum was observed in the 37°C samples. As noted earlier, the recovery of elasticity (MC) was not greatly different for the xanthan gum frankfurter gels than for the others, but the other properties were much better preserved. Similar results were obtained for frankfurters with carrageenan gum, but none of the other additives studied had any effect.

Xanthan gum concentrations

As seen in Fig. 4, increasing concentrations of xanthan gum resulted in a significant ($P < 0.05$) decrease in resistance to penetration in the initial samples. The W-B shear results were similar. The acid-hardening of the samples upon storage was the same for all three xanthan gum levels, and was greater than that of the control. After the initial hardening phase, the texture of all samples deteriorated, but not as fast as had been observed in the other sets. After 4 wk of storage, the controls were still as firm as the xanthan gum frankfurters, and it was not until after 3 mo of storage that the controls became soft. The final P values were the same for all three xanthan gum levels, and there seems to be no advantage in xanthan gum levels higher than 0.5%, especially since the higher levels resulted in softer frankfurters initially.

Mushiness

From evaluations made while performing the Instron measurements, we observed that samples with P values below 175–200g, W-B shear below 750–900g, D/C ratios less than 0.2, or CF below 300g were mushy, that is, lacked the characteristic elastic bite of a frankfurter. From visual observations of the compression process, the mushy samples flowed smoothly with almost no dimensional recovery, whereas nonmushy samples tended either to fracture into discrete fragments or to recover almost all the original dimensions. At no time, even after 6 mo of storage, did any of the frankfurters containing xanthan or carrageenan gum become mushy.

Time of addition

Since the process of forming frankfurter emulsions involves the salt extraction of the muscle proteins, particularly the contractile proteins, and because it was suspected that protein-gum interactions were involved, we varied the time of xanthan gum addition (set 4). Adding the gum with the salts meant adding it at a time when the proteins were still insoluble. Adding it after salt but prior to fat addition allowed time for the gum to interact with the solubilized proteins, whereas adding after fat addition gave the fat time to interact with protein before the gum could do so. The time of addition made no difference since the measured properties were the same for all three batches of frankfurters. In practice, the best technique was to sprinkle the dry gum over the emulsion between the times of addition of spice and fat. When added with the spice or as a gel, the gum tended to adhere to the surface of the bowl, requiring much scraping to loosen it.

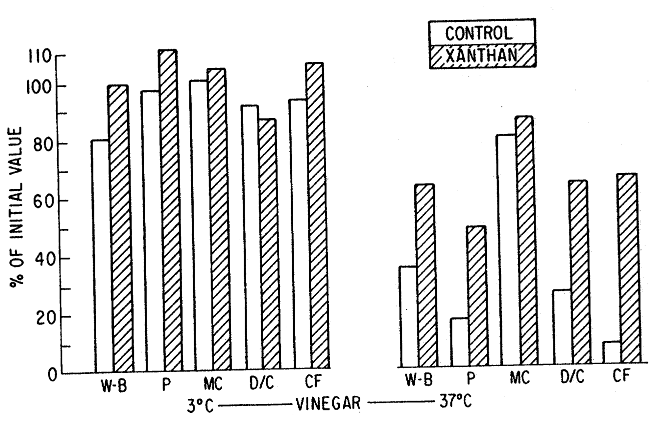

Fig. 3—Average results for Warner-Bratzler shear, penetration, multiple compression, decompression/compression, and maximum compressive force for the frankfurters of set 5, after 19 days, expressed as percent of the initial values.

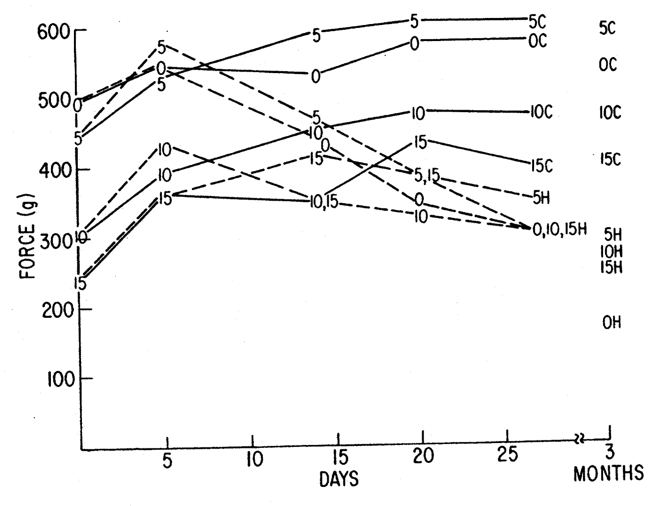

Fig. 4—Force required to penetrate (P) frankfurters with varying levels of xanthan gum (set 3). 0, no xanthan; 5, 0.5%; 10, 1.0%; 15, 1.5% xanthan gum; C, (——), 3°C; H, (- - -), 37°C.

DISCUSSION

FROM THE FOREGOING observations it may be deduced that the addition of anionic gums to meat emulsions produces a structure akin in its properties to the structure formed by the muscle proteins, but with two differences: it was not acid-labile, and it retained water better. The gum structure does not appear to be formed independently of the protein gel itself since the initial properties of shear, elasticity, and compressibility were no greater for the anionic gum samples than for the other samples; that is, the properties were not additive. Had there been both a gum and a protein gel structure, the frankfurters with gum would have been firmer initially than the controls. Furthermore, increasing the xanthan gum concentration above 0.5% resulted in increasingly softer gels, which would result if the softer gum gel was being produced at the expense of the harder protein gel. In this case either the protein, fat, or both are interacting with the gum. Protein-gum interactions have been observed between anionic gums and casein, but not between casein and neutral gums (Elfak et al., 1979). That ionic gums stabilize frankfurter texture while neutral gums do not is strong presumptive evidence that the frankfurter gel structure was also produced by a gum-protein interaction. When formed from a cationic gum, the gum-protein structure will not hold water. At the pH of meat the muscle proteins are on the alkaline side of their pK_a, hence they have a negative charge. The resulting gel formed with a positively charged gum would be much less ionic than either component, and would not hold water as well, which would account for the poor water-binding capacity of the frankfurters containing chitosan.

Advantages of xanthan gum

In terms of their effectiveness in stabilizing frankfurter gels against deterioration in vinegar pickle at high room temperatures, the ionic gums had no equivalent. None of the proteins tested had any effect, possibly due to the low level of addition. None of the neutral gums had any effect on the acid stability or on the inital texture. Carrageenan was effective in stabilization of the frankfurters against acid deterioration, and is approved for use in meats, but it has come under criticism recently and its safety is being reviewed (Food Chemical News, 1981). While chitosan reacted with meat components during processing to form a stable structure, its emulsifying properties were not as good as the anionic proteins. The frankfurters with chitosan developed fatcaps during processing, lost water during cooking, and had a faint fishy odor. By contrast, in addition to forming an acid-stable gel, xanthan gum has other felicitous operational and functional properties (Rocks, 1971). Solutions of xanthan gum are more pseudo-plastic than those of any other gum now available, which means that at the very high velocities of the blades used for emulsion manufacture, xanthan gum does not increase the viscosity greatly, thereby lowering temperature rise during chopping. Xanthan gum solutions are resistant to thermal decomposition and the gum is fully compatible with salt, both properties important to an emulsified meat product. Xanthan gum has the unusual property of forming dimensionally stable gels in combination with locust bean gum (Rocks, 1971). In this study, we did not observe any properties in the frankfurters with the combination that could be attributed specifically to such an interaction, since the Xanthan/locust bean (X/LB) frankfurters showed properties identical to the frankfurters with xanthan alone. Xanthan gum has been approved for use in certain meat products (9CFR) although not for this specific use. We conclude that for the purpose of stabilizing the frankfurter gels against acid deterioration, xanthan is the gum of choice, although carrageenan is equally effective.

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