Comminuted meat products: Factors affecting the gelation of the water phase isolated from the batter

K. FRETHEIM & S.Aa. GUMPEN

Norwegian Food Research Institute, P.O.B. 50, N-1432 Ås-NLH, Norway

INTRODUCTION

Successful formulation in the meat processing industry should provide for trouble-free manufacture, at the least cost, of products meeting preset quality standards. Accordingly, as the prices and availability of raw materials fluctuate recipes and procedures must be adapted. Maintenance of the desired textural quality is a major challenge in this process of formulation. The fundamental problem is our insufficient knowledge of how various factors interplay to produce different textures.

Protein gelation constitutes one of these factors. In our previous contributions we have reported on various aspects of the heat-induced gelation of ovalbumin solutions (Fretheim & Gumpen, 1979) and blood plasma (Fretheim & Gumpen, 1978; Gumpen & Fretheim, 1980). Our present report is the result of an attempt at drawing closer to the extremely complex texture-forming system of a commercial batter. By working with the aqueous phase isolated from a simplified sausage batter we hope to link possible effects of the fat ingredient on gelation to reasonably well defined interactions at the molecular level. So far we have met with limited success.

MATERIALS AND METHODS

Formulation: 1 kg lean beef (4.5% fat, 20.5% protein), 0.38 kg pork backfat (87.2% fat, 2.8% protein) or 0.34 kg food grade soybean oil plus 0.04 kg water, 37.5 g NaCl, and 0.45 l water.

Inducing low quality in pork backfat: A batch of the usual chunked backfat was ground through 3 mm grinder plate and distributed in a 1 cm layer in a deep tray. Heating in a water bath (45°C) under UV light overnight left the fat partially melted and the peroxide value had been raised from about 0.1 to 9.

Oxidation of soybean oil: Oxidation was promoted by bubbling air through the heated (60°C) oil while shining UV light on the flasks containing the oil. The length of the treatment, from one day upwards, determined the degree of oxidation produced.

Characterization of fatty raw materials used: Peroxide numbers were determined (in duplicate) by the method described by Hadorn et al. (1956). The thiobarbituric acid values for soybean oils were determined according to Sidwell et al. (1954).

Comminution (in a lab-scale bowl chopper, "Scharfen", W.-Germany): The frozen preground meat was thawed and tempered to about 4°C before being emptied into the pre-cooled chopper. The chopping procedure was strictly standardized, giving a final temperature of about 15°C in the batter.

Isolation and preparation of water phase (WPh): The obtained batter was transferred to tubes (250 ml) for centrifugation (Beckman J-21C, JA 14 rotor) at 20°C and 14 000 rpm for 90 minutes. The separated water phase was drained from the tubes and cooled in a refrigerator to solidify contaminating fat. After filtration through a sintered filter the water phase was centrifuged (Beckman L5-75, rotor 45 Ti) in polycarbonate tubes (70 ml) at 4°C and 35 000 rpm for 1 hour. The obtained supernatant was preserved by addition of 10% aq. sodium azide to yield a 0.02% solution, and the pH was adjusted from an original of about 5.4 to 6.00 by adding 1N NaOH. Finally, grains of sodium chloride were added to the solution while stirring, and WPh of standard conductivity 32.0 S (about the same conductivity as 0.5 M aq. NaCl) was obtained. The protein concentration, determined by the Biuret method, varied from batch to batch, being about 5 ± 0.5%.

Preparation of samples for studying the effect of aldehydes on gelation: 5 sets of 10 ml solutions were employed which all contained 9 ml WPh. The composition of the remaining 1 ml is explained in Table 1. Salt was added both to keep the WPh proteins dissolved and because the malonaldehyde solution employed was about 0.3 M in NaCl.

Preparation of samples for studying the effect of free fatty acids (FFA) on gelation: WPh was initially given a heat treatment by placing 2 x 160 ml of the solution in 250 ml flasks in a water bath at 56°C for 5 minutes. After subsequent centrifugation (Beckman L5-75, rotor 45 Ti) at 35 000 rpm for 90 minutes at 4°C lauric acid was added to one half of the heat treated WPh by the Celite method of Spector and Hoak (1969); the other half was treated similarly with pure Celite. Another round of centrifugation removed the Celite from the solutions, and the obtained concentration of lauric acid was determined colorimetrically in accordance with Anderson and McCarty (1972). The standard curve was obtained by analyzing appropriate solutions of lauric acid. After checking pH and conductivity the protein concentrations were equalized by dilution with 0.5 M NaCl.

Table 1:
Composition of the samples (10 ml) used for evaluating the effect of aldehydes on gelation; all samples contained 9 ml of standard water phase.

R: Reference samples, i.e. standard water phase adapted to the concentrations employed in the experiment.
I: Samples of reduced hydrophilicity due to addition of isopropanol.
A: Samples containing acetaldehyde
B: Samples containing 2-butenal
M: Samples containing malonaldehyde

Components (µl)	R	I1	I2	I3	I4	I5	I6	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	M1	M2	M3	M4
1.4 M aq. NaCl	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	189	167	100	
Distilled water	800	795	780	740	620	440	80	794	782	746	692	584	440	789	768	705	611	422	170	758	673	421	43
Isopropanol		5	20	60	180	360	720																
Acetaldehyde								6	18	54	108	216	360										
2-butenal														11	32	95	189	378	630				
Malonaldehyde-solution[1]																				53	160	479	957

[1]Prepared from 1,1,3,3-tetramethoxypropane in accordance with Chiba et al. (1976).

Gelation and rigidity measurements: Gels were produced from 10 ml samples and their rigidity measured as described elsewhere (Gumpen & Fretheim, 1980). An Instron plunger speed of 50 mm/sec was employed, and the force reading at 4 mm, or alternatively at 5 mm, penetration into the gel was taken as a measure of gel rigidity.

RESULTS AND DISCUSSION

It has been stated by Karel (1977) that "Properties of proteins in food systems depend heavily on the interactions of proteins with other components, especially water and lipids".

Figure 1 shows that the type and/or state of the lipid are important. The pork backfat which had been mistreated to become of low quality appears to impair the gelling ability of the corresponding WPh. This is not really surprising, any sausage maker would expect to obtain a bad product when using bad raw materials. Nevertheless, in referring at least part of the practical problem to the WPh of the batter we are one step closer to pinpointing why a texturally bad product results.

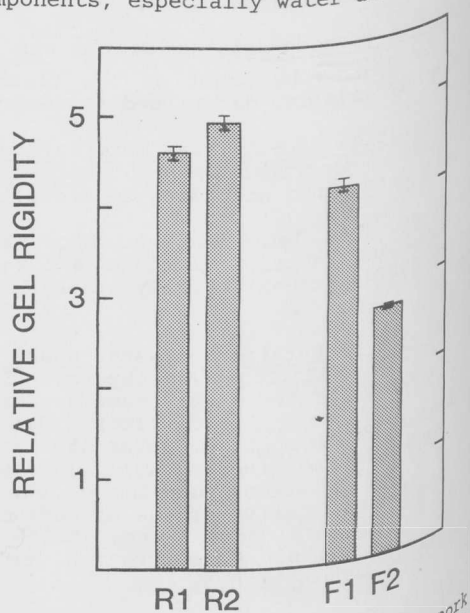

Figure 1: Effect of low quality pork backfat as an ingredient in a sausage batter: Rigidity of gels obtained by heating the water phase isolated from the batter. The bars indicate the respective standard errors.
R1, R2: Gels of two reference water phases; 9 and 6 gel replicates, respectively.
F1, F2: Gels derived from two batters made with low quality fat; 8 and 14 gel replicates, respectively.

However, ground and partially melted/oxidized pork backfat differs in a number of ways from its fresh, high quality counterpart. To investigate if oxidation of the fat constitutes a critical factor batters were made with soybean oils which varied in their extents of oxidation. The results are depicted in Figure 2. Clearly, oxidation of the oil has an ill effect. It is surprising and difficult to explain, however, that the degree of oxidation does not seem to be of importance. The experimental results are a bit too limited, however, to validate much speculation regarding this observation. Two possible interpretations lie close at hand, though: The effect of oxidized fat is limited, being reached in all three cases, or the substance(s) having the effect quickly attain a nearly constant effective concentration when fat is oxidized. It should be pointed out that Figure 2 resulted from gelation of WPh's isolated after storing the prepared batters overnight, i.e. lipid-derived reactants were allowed time to interact with the gel-forming proteins. Table 2 shows the average reductions in gel rigidity in terms of per cent. The table also includes data for one experiment in which the batter was subjected to centrifugation immediately after preparation. The result suggests

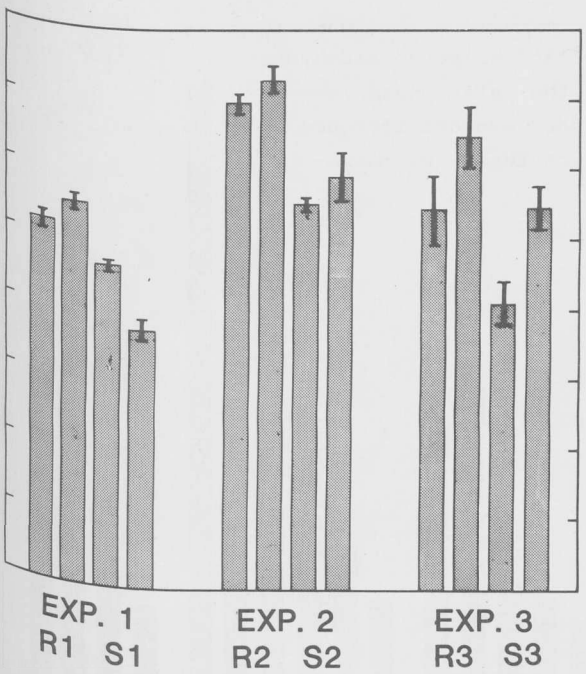

Figure 2: Effect of oxidized soybean oil on the rigidity of gels derived from sausage batters made with oil as the fat ingredient; different batches of meat were used in the three experiments. The bars indicate the respective standard errors. Denotations (number of gel replicates in parentheses):
R1 (13,8), R2 (7,8), R3 (8,8): Duplicate sets of reference gels derived from 3 x 2 batters made with fresh soybean oil.
S1 (15,5): Gels derived from batters made with soybean oil of peroxide value (PO) = 17.
S2 (8,8): Cfr. S1; PO = 32, thiobarbituric acid value (TBA) as expressed in mmoles malonaldehyde/g oil = $6 \cdot 10^{-6}$.
S3 (8,7): Cfr. S1 and S2; PO = 190, TBA = $5 \cdot 10^{-5}$.

that an extended interaction period is indeed of importance.

With reference to our findings (Fretheim & Gumpen, 1979) of how malonaldehyde affects the gelation of ovalbumin the effect of various aldehydes on WPh gelation was investigated. The results are shown in Figure 3. It is obvious that as far as these selected secondary products of lipid oxidation are concerned gelation is not impaired. The observed increase in relative gel rigidity may be said to parallel the reported initial increase in ovalbumin gel rigidity after interaction with malonaldehyde (Fretheim & Gumpen, 1979). However, addition of the larger volumes of the aldehydes, especially 2-butenal, was seen to cause precipitation in the respective WPh samples. These aggregates may well have exerted the same positive "particle effect" on overall gel rigidity as previously reported for blood cells and meat particles (Gumpen & Fretheim, 1980). Thus, gel rigidity per se has not necessarily been increased. On the other hand, it appears unlikely that a detrimental effect is exerted. The results obtained when adding isopropanol to the WPh, cfr. Figure 3, indicate quite strongly that a simple increase in the hydrophobicity of the WPh does not significantly affect gel rigidity.

Table 2:
Effect of oxidized lipids (soybean oil) as ingredients in a batter: Relative decrease in the rigidity of gels obtained by heating the water phase isolated from the batter; average values.

	Relative, recalculated rigidities	
	Reference gels	Gels affected by oxidized lipids
Experiment 1[1]	100	78
Experiment 2[1]	100	80
Experiment 3[1]	100	80
Experiment A[2]	100	92

[1]cfr. Figure 2; batters stored overnight prior to isolation of water phase.
[2]Water phase isolated right after production of the batter.

We have previously reported (Fretheim & Gumpen, 1978; Gumpen & Fretheim, 1980) that free fatty acids impair the ability of plasma albumin to form firm gels. When subjecting WPh to a similar investigation no significant effect could be detected. Shenouda and Pigott (1974) have shown, however, that thermal or mechanical treatment of myosin solutions render the protein more prone towards interaction with lipids. Accordingly, WPh was heat treated at 56°C and subjected to subsequent interaction with lauric acid as described above. All the same, no significant effect on gel formation could be detected in spite of our attaining as much as an approximate five-fold increase in the FFA-concentration of the WPh (up to about 0.5 mmoles FFA/l WPh). But, again, Shenouda and Pigott (1974) showed that the type of lipid available for interaction is quite decisive for the extent to which myosin is affected. Thus, no general conclusion about the possibility of lipid interaction with WPh proteins can be drawn; further investigations are necessary.

CONCLUSION

It has been shown that heat treatment of the water phase isolated from sausage batters made with low quality fat, for example oxidized soybean oil, yields gels of about 20% lower rigidity than when high quality (nonoxidized) fat has been used. Experiments performed up to now

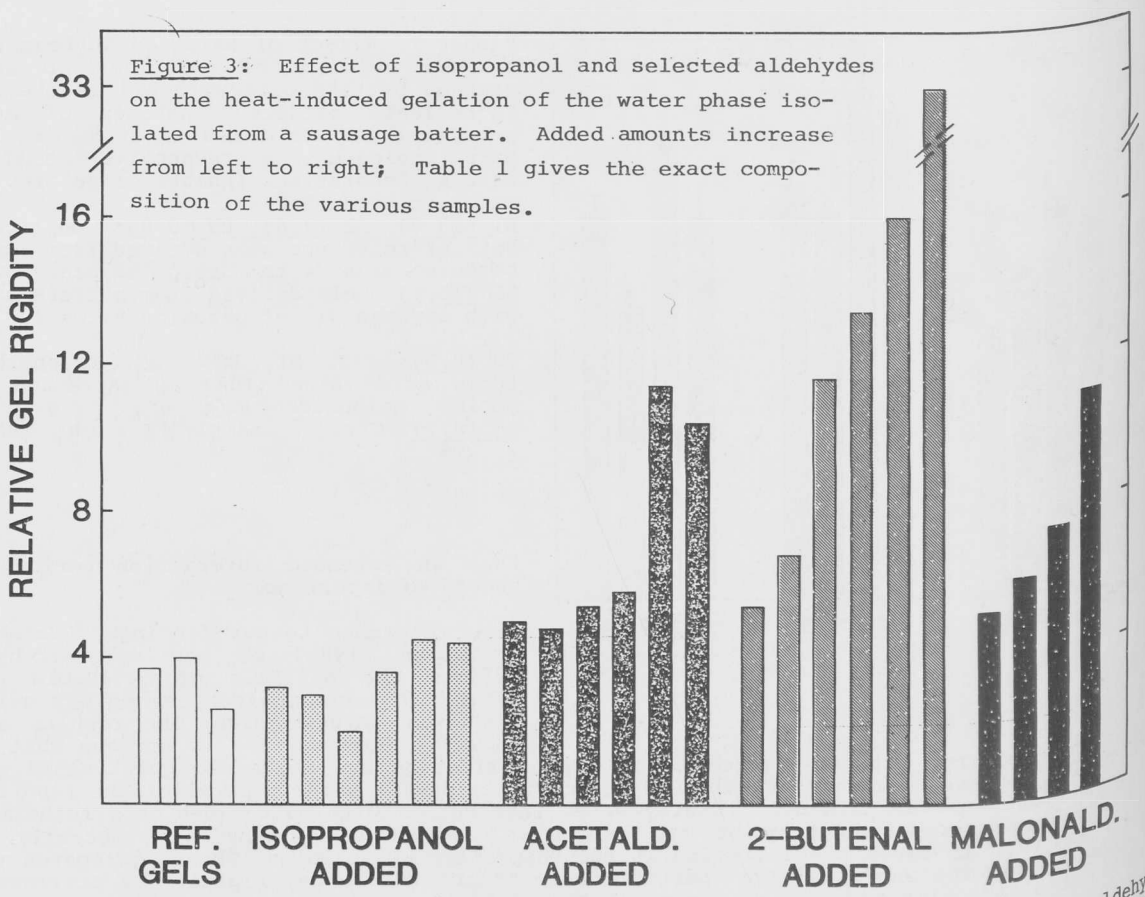

Figure 3: Effect of isopropanol and selected aldehydes on the heat-induced gelation of the water phase isolated from a sausage batter. Added amounts increase from left to right; Table 1 gives the exact composition of the various samples.

have failed to link the observed effect on gelation to the action of selected aldehydes produced by lipid oxidation or to protein interaction with free fatty acids, i.e. lauric acid.

ACKNOWLEDGEMENTS

The pleasant cooperation of Kari Hanssen, Geir Johnsen and Karin Solgaard in carrying out the experiments has been much appreciated.

LITERATURE

Anderson, M.M. & McCarty, R.E. (1972). Anal. Biochem. 45, 260.
Chiba, H., Doi. H., Yoshikawa, M. & Sugimoto, E. (1976). Agr. Biol. Chem. 40 (5), 1001.
Fretheim, K. & Gumpen, S.Aa. (1978). 24th Europ. Meet. Meat Res. Work., Kulmbach, Proceedings H 9:3.
Fretheim, K. & Gumpen, S.Aa. (1979). 25th Europ. Meet. Meat Res. Work., Budapest, Proceedings 473.
Gumpen, S.Aa. & Fretheim, K. (1980). 26th Europ. Meet. Meat Res. Work., Colorado Springs, Proceedings C-4 (p. 108).
Hadorn, H., Biefer, K.W. & Suter, H. (1956). Z. Lebensm.-Unters.-Forsch. 104, 316.
Karel, M. (1977). In "Biotechnological Applications of Proteins and Enzymes", Z. Bohak & N Sharon (eds.), Academic Press, New York, 317.
Shenouda, S.Y.K. & Pigott, G.M. (1974). J. Food Sci. 39, 726.
Sidwell, C.G., Salwin, H., Benca, M. & Mitchell jr., J.H. (1954). J. Amer. Oil Chem. Soc. 31, 603.
Spector, A.A. & Hoak, J.C. (1969). Anal. Biochem. 32, 297.