Comminuted Meat Emulsions: Relation of the Melting Characteristics of Fat to Emulsion Stability

C. E. Swift, W. E. Townsend and L. P. Witnauer
Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture, Philadelphia, Pennsylvania 19118

SUMMARY

The investigation was concerned with the relation of the melting characteristics of fats to the stability of meat emulsions containing them. Rendered pork and beef fats were each fractionated into four fractions having widely different melting characteristics as determined by differential thermal analysis (DTA). Meat formulas containing either 12% or 22% of either fractions or of the original fats were comminuted to maximum temperatures ranging from 12.8 to 35°C. The stability of the emulsions was determined.

All emulsions containing only 12% added fat were stable. The stability of emulsions containing 22% added fat depended principally on the melting characteristics of the fats. The high-melting fats yielded stable emulsions and low-melting oily fats yielded unstable emulsions, irrespective of temperatures attained during emulsification. A third group yielded relatively stable emulsions even though melting produced liquefaction during comminution. In addition, stable emulsions were produced with 22% of added oily fat when it was added in portions. The results reflect the importance of rate of release of oily fat as a determinant of emulsion stability.

INTRODUCTION

Specifications for formulating and processing emulsion-type sausage products, such as frankfurters and bologna, include those designed to assure stability when the products are heat processed. Content of fat and the maximum temperature to be attained during comminution are among factors considered important. Information on the specific relation of these factors and their interaction to emulsion stability can afford improved guidelines in improving emulsion quality and the use of meat raw materials, as well as in improving equipment and methods.

In the earlier work of the authors (Townsend *et al.,* 1968) the melting characteristics of meat fats were investigated to determine how much melting occurs during comminution and whether this bears a relation to emulsion stability. The results showed that some melting is inevitable when typical meats are comminuted under the usual conditions. The fact that melting of a major part of the fats began at approximately 18°C appeared especially important, since it was observed that, at this and higher temperatures, increasing temperature concurrently increased melting and decreased emulsion stability. The temperatures associated with emulsion breakdown were essentially in agreement with those cited by other authors (Hansen, 1960; Helmer *et al.,* 1963).

Further investigation has been concerned with determining if the events observed are related, or merely coincidental. It involved studying the emulsification of special fats obtained by fractionating animal fats into components ranging from oils to high-melting fats, using differential thermal analysis and emulsion stability tests to obtain necessary data. The results proved to have broader implications than merely to answer the question above. They provide insight regarding the importance of content, composition, and melting of fats; of temperature; and of the interaction of these, as determinants of the rate of release of oily fats and of emulsion stability.

EXPERIMENTAL

Rendering and fractionation of fats. Internal and external beef and pork fats were physically separated from commercial grade cow beef and market weight hog carcasses that had been stored at 3°C for 72 hr after slaughter. Each type of carcass fat was ground once through a 3/16-in plate and rendered in a steam jacketed kettle. The fat was strained to remove cracklings, poured into lard containers, cooled, and stored at 3°C until fractionated or used in preparing emulsions.

The principal steps used for fractionating the fats are shown by Fig. 1. These steps involved:

1) dissolving 2,270 g of melted rendered fat in 16,000 ml of acetone;
2) cooling the fat-acetone mixture with dry ice and filtering to remove the fractions, which crystallized at 6°, −13°, and −28°C, retaining the filtrate;
3) and, removal of acetone by bubbling nitrogen through the fractions, which were heated to *ca* 105°C. The fractions of fat were held at 3°C until used.

The remaining portion of the beef and pork carcasses were separated into lean beef and pork and stored at −19°C until ready to use.

DTA of fractionated fats. The various fat fractions were melted, samples placed in DTA glass tubes, held overnight at 3°C and analyzed according to the procedure previously described by Townsend *et al.* (1968).

Preparation of emulsions. Emulsions were prepared in which 12 and 22% of each type of fat was added to the lean pork-beef mixture. The basic sausage formula for each batch consisted of 800 g each of lean beef and pork, 192 g fat (12% level) or 352 g fat (22% level), 400 g flaked ice, plus

seasoning, cure, sugar and salt.

Twenty-four hr before the emulsions were made, the lean beef and pork were ground through a 3/16-in grinder plate and thoroughly mixed. The fats were melted, when necessary, and sprayed onto meat mixtures held at 3°C. The operations also involved frequent mixing. This spraying procedure was done to obtain uniform distribution of the fat throughout the lean meat. The meat-fat mixtures were held overnight at 3°C.

The chilled meat-fat mixture was chopped in a silent cutter as described by Townsend *et al.* (1968). Samples were taken for emulsion stability tests when the temperature had risen from 3°C to 12.8°C (8 min); 18.5°C (10 min); 24.0°C (13 min); 29.5°C (16 min); and in several instances 35.0°C (19 min).

To investigate the effect of adding 22% liquefied fat, in portions, as compared with one addition, combined fractions C and G were added to the meat mixtures in one portion, or in four portions as follows: 5% added to the original meat mixture; 5% when the temperature of the emulsion had risen to 5°C (3 min); 5% at 7°C (6 min), and 7 % at 10°C (8 min). Chopping was continued and samples were taken for emulsion stability tests when the temperature had risen to 12.8°C (10 min); 18.5°C (12 min); 24.0°C (14 min) and 29.5°C (17 min).

Emulsion stability test. The stability test used was that described by Townsend *et al.* (1968).

RESULTS AND DISCUSSION

Fig. 1 shows an outline of the procedure used in fractionally crystallizing rendered pork fat from acetone to obtain fractions A, B, C and D. Employing the same procedure with beef fat yielded corresponding fractions E, F, G, and H weighing 665, 741, 400 and 464 g, respectively. The procedure was modeled after a more thorough fractionation described by Riemenschneider *et al.* (1946) and satisfactorily separated principal fractions as needed for the present work.

The curves obtained by DTA of rendered pork fat and its fractions are shown in Fig. 2. The melting pattern of the whole fat, R_p, shows peaks at −3°, 12°, 29.5° and an inflection at 42.2°C. The pattern shown, obtained after chilling rendered fat for one day, and another obtained after chilling seven days, were essentially the same. The pattern differs markedly from that of pork tissue fats, which primarily melt in two ranges, one extending from 8° to 14° and another from 18° to 30°C, or that of tissue fats that have been heated to 60°C and then chilled before remelting (Townsend *et al.,* 1968). A possible explanation is that the pattern of crystallization of fats in fatty tissues may reflect a natural arrangement of the fats *in situ,* while rendered fat having been completely mixed by rendering, solidifies on cooling in arrangements determined by composition and rate of cooling.

The curve for fraction A shows melting extended from 15–20° to 35°C; that of fraction B shows two melting ranges, from −10 to 8° and from 8 to 13.5°C; that of fraction C shows one peak with melting from −15 to 1°C; and that of fraction D one peak with melting from below −30 to slightly above −20°C. More than 50% of the rendered pork fat was low-melting, since fractions C and D comprised over 40% and an appreciable portion of fraction B was also low-melting.

The DTA curves of whole rendered beef fat, R_b, and of fractions E, F, G and H, are shown in Fig. 3. The whole fat melted over a broad range, with peaks at 13, 18, and 41°C having little resemblance to curves obtained with beef tissue fat (Townsend *et al.,* 1968), possibly for the reason proposed in discussing pork tissue fat. The DTA curve for fraction E shows

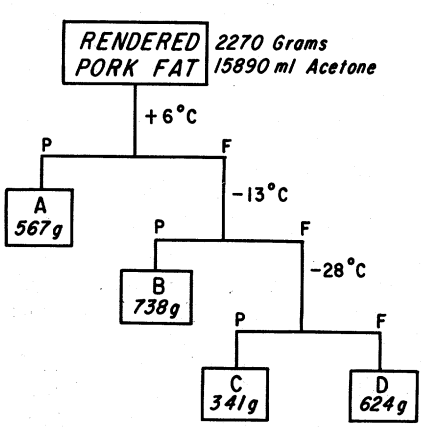

Fig. 1. Fractional crystallization of rendered pork fat from acetone. P and F represent precipitate and filtrate, respectively.

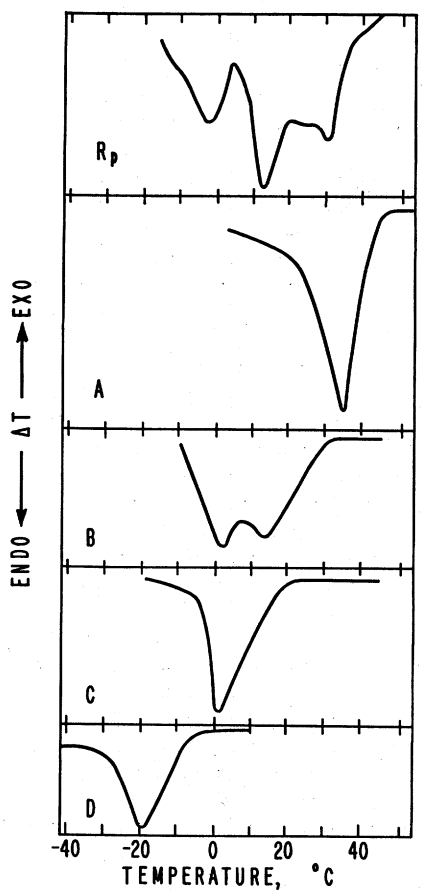

Fig. 2. DTA curves of rendered pork fat, R_p, and fractions A, B and C that crystallized from acetone at +6°, −13° and −28°C, respectively, and D, the fraction in the filtrate.

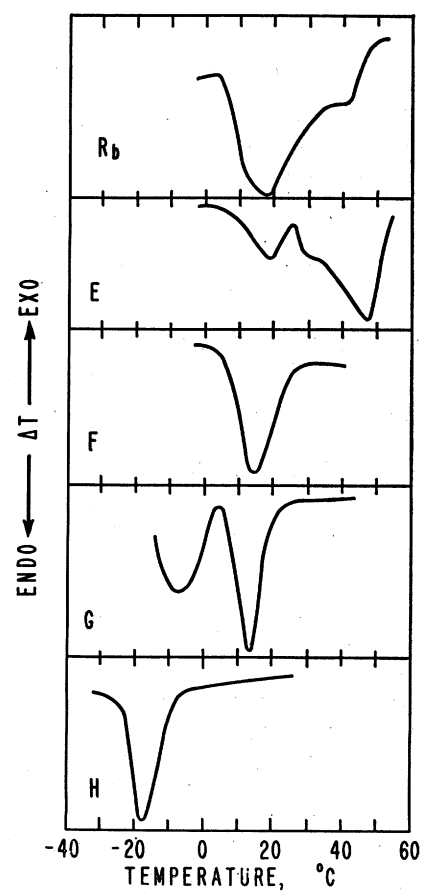

Fig. 3. DTA curves of rendered beef fat, R_b, and fractions C, D and E, which crystallized from acetone at +6°, −13°. and −28°C, respectively, and H, the fraction in the filtrate.

Table 1. Effect of varying melting characteristics of pork fat on the stability of emulsions chopped to different temperatures.

Maximum temperature during emulsification	Fat released from emulsions on cooking, ml/100 g [1]									
	Rendered beef fat (R_b)		Fraction							
			A		B		C		D	
	12%	22%	12%	22%	12%	22%	12%	22%	12%	22%
°C										
12.8	0.6 ± 0.0	0.8 ± 0.1	0.4 ± 0.1	0.3 ± 0.0	0.3 ± 0.0	0.1 ± 0.2	0.8 ± 0.1	4.7 ± 0.3	0.3 ± 0.0	4.1 ± 0.2
18.5	0.6 ± 0.0	2.4 ± 0.2	0.6 ± 0.0	0.5 ± 0.1	0.3 ± 0.0	0.3 ± 0.0	0.6 ± 0.0	5.3 ± 0.7	0.3 ± 0.0	3.8 ± 0.1
24.0	1.0 ± 0.2	4.7 ± 0.2	0.5 ± 0.1	0.6 ± 0.0	0.3 ± 0.0	0.5 ± 0.1	0.8 ± 0.1	6.2 ± 0.9	0.3 ± 0.0	6.3 ± 0.2
29.5	1.5 ± 0.0	7.0 ± 0.3	0.6 ± 0.0	0.6 ± 0.0	0.6 ± 0.0	0.3 ± 0.0	1.1 ± 0.1	5.2 ± 0.7	0.6 ± 0.0	6.4 ± 0.3
35.0	———	———	0.6 ± 0.0	0.6 ± 0.0	———	0.4 ± 0.1				

[1] Average value of three samples tested ± standard deviation.

Table 2. Effect of varying melting characteristics of beef fat on the stability of emulsions chopped to different temperatures.

Maximum temperature during emulsification	Fat released from emulsions on cooking, ml/100 g [1]									
	Rendered beef fat (R_b)		Fraction							
			E		F		G		H	
	12%	22%	12%	22%	12%	22%	12%	22%	12%	22%
°C										
12.8	0.3 ± 0.0	0.9 ± 0.0	0.9 ± 0.0	0.6 ± 0.0	0.3 ± 0.0	0.6 ± 0.0	0.3 ± 0.0	3.6 ± 0.2	0.3 ± 0.0	———
18.5	0.5 ± 0.1	1.0 ± 0.2	0.9 ± 0.0	0.4 ± 0.1	0.6 ± 0.0	1.6 ± 0.1	0.3 ± 0.0	3.7 ± 0.2	0.3 ± 0.0	———
24.0	0.7 ± 0.1	1.0 ± 0.1	0.9 ± 0.0	0.6 ± 0.0	0.9 ± 0.0	1.6 ± 0.2	0.5 ± 0.1	4.3 ± 0.1	0.6 ± 0.0	———
29.5	1.3 ± 0.1	4.5 ± 0.5	0.8 ± 0.1	1.0 ± 0.2	1.1 ± 0.1	2.3 ± 0.2	0.6 ± 0.0	5.0 ± 0.3	0.6 ± 0.0	———
35.0	———	———	———	———	1.2 ± 0.0	1.5 ± 0.0	———	———	———	———

[1] Average value of three samples tested ± standard deviation of mean.

that it was a high-melting fat with a major portion melting from approximately 27° to 47°C and a smaller portion from 5–10° to approximately 19°C. The curve for fraction F shows one peak with melting from 5° to 15°C, while that for fraction G shows two melting ranges, one extending from about −15° to −8° and another from about 7° to 13.5°C. The curve for fraction H shows one peak with melting extending from approximately −25° to −17.5°C. Although beef fat is considered to be high-melting, it is notable that fractions G and H, the low-melting fractions, represented 38% of the original fat.

Tables 1 and 2 show the results of stability tests on emulsions prepared by adding 12 or 22% additional rendered pork or beef fat, or their fractions, to the basic meat formula and comminuting to different maximum temperatures ranging from 12.8 to 35°C. Owing to the presence of inseparable fat in the meat raw materials, part of the fat could not be varied and the total content of fat was higher than indicated levels. Emulsions that released 1.0 ml, or less, fat on cooking were judged stable; those releasing 1.1 or 1.2 ml were judged possibly somewhat unstable, and those releasing 1.3 ml or more were judged unstable.

As shown in Table 1, the emulsions containing 12% added rendered pork fat were unstable if chopped to 29.5°C or higher and those containing 22% when chopped to 18.5°C or higher. These results indicate that stability is an inverse function of both fat content and temperature in emulsifying a fat that melts over a broad range, such as pork fat. Emulsions containing high-melting fractions A and B were stable irrespective of either fat content or comminution temperature. It should be noted that comminution at temperatures in the upper ranges brought about some melting of fraction A and considerable melting of fraction B. The data show that emulsions containing 12% of fractions C and D were stable, irrespective of temperature, except possibly that containing fraction C and chopped to 29.5°C. Those containing 22% of those portions were unstable on comminution at any of the temperatures. The results indicate that the meat was capable of emulsifying these oily fractions if present at 12%, but not at 22%, irrespective of the temperatures attained during comminution.

The data in Table 2 indicate that the stability of emulsions made from beef fat and its fractions was affected by the content and the characteristics of fat and by the temperature attained during comminution. The emulsions containing either 12 or 22% rendered beef fat were stable, except those chopped to 29.5°C, and, under comparable conditions, were more stable than those prepared with rendered pork fat, a fact that bears out an earlier report that beef fats can be chopped to higher temperatures than pork fats (Shannon, 1966). None of the emulsions containing high-melting fraction E were unstable, while there was evidence of some instability in emulsions containing 12% fraction F when chopped to either 29.5° or 35°C, and marked in stability in emulsions containing 22% of this fraction when chopped to 18.5°C or higher. Emulsions containing 12% of oily fraction G were stable irrespective of temperature of comminution, and those containing 22% were unstable. Emulsions containing 12% of fraction H were also stable after comminution at any temperature.

Judging from the DTA curves obtained for fractions E and F, in comminuting emulsions containing these fractions to the temperatures indicated in Table 2 some melting of fraction E occurred and fraction F melted considerably, yet emulsions containing 22% of fraction E were entirely stable and those containing fraction F were relatively so. Similarly, judging from the DTA curve for fraction B, the fat became entirely melted on comminution at temperatures ranging upwards

Table 3. Effect of two rates of addition of liquid fat on emulsion stability.

Maximum temperature during emulsification	Volume of fat released, ml/100 g emulsion: Fat added in four portions totalling 22%	One addition of 22% fat
12.8	0.0 ± 0.0	1.9 ± 0.0
18.5	0.0 ± 0.0	1.5 ± 0.1
24.0	0.3 ± 0.0	1.3 ± 0.1
29.5	0.3 ± 0.0	1.6 ± 0.2

from 18.5°C, yet stable emulsions were obtained as indicated in Table 1. These results indicate that the meat bound only a limited amount of added oily fats, more than 12% but less than 22%, and that a total of 22% of oily fat was effectively bound if a significant part was produced through melting. An explanation is that the capacity of meat to emulsify oily fat is extended if the fat becomes gradually available, as from melting.

The data in Table 3 shows the results of testing the hypothesis that the rate oily fat becomes available is a factor affecting stability. The fat used was oily at all four maximum temperatures of comminution. The results indicate that slow addition permitted stable emulsions to be produced from oily fat, irrespective of the temperatures attained during comminution. Results support a conclusion that the stability of emulsions produced with 22% added fats, which ultimately melted, as compared with the instability of those prepared with 22% oily fat, can be attributed to the fact that oily fat was slowly produced. Furthermore, an explanation of the results obtained with 22% of the oily fractions C, D, G and H is that coalescence occurred early during comminution and that the shearing force applied was incapable of producing a necessary degree of dispersion. It would appear that an emulsion was never formed, accepting coalescence as a condition associated with emulsion breakdown (Becher, 1965), unless the fat became available in portions. A measured rate of release of oily fat is readily obtained in emulsifying high-melting fats and, to a somewhat less extent, in emulsifying fats that melt over a range. The fact that stable emulsions were readily produced when this rate was obtainable, even in emulsifying oily fat, supports a conclusion that this rate is critical. Conversely, the results show that other conditions, such as temperature and type of fat, are not critical, except in relation to this principal factor. On the basis of this, emulsion preparation should involve control of fat materials, the rate and extent of temperature rise, and the rate of dispersion in comminution so as to optimally affect the rate of release of oily fats.

REFERENCES

Becher, P. 1965. "Emulsions: Theory and Practice." 2nd Ed. Reinhold Publishing Corp., N. Y.

Hansen, L. J. 1960. Emulsion formation in finely comminuted sausage. *Food Technol.* **14**, 565.

Helmer, R. L. and Saffle, R. L. 1963. Effect of chopping temperature on the stability of sausage emulsions. *Food Technol.* **17**, 1195.

Riemenschneider, R. W., Luddy, F. E., Swain, M. L. and Ault, W. C. 1946. Fractionation of lard and tallow by systemic crystallization. *Oil and Soap* **23**, 276.

Shannon, W. 1966. What's happening in sausage manufacture. *Nat. Provisioner* **154**(11), 80.

Townsend, W. E., Witnauer, L. P., Riloff, J. A. and Swift, C. E. 1968. Comminuted meat emulsions: differential thermal analysis of fat transitions. *Food Technol.* **22**, 319.

Ms. accepted 3/4/68.

Grateful acknowledgment is made to William Palm and B. S. Blinkoff for the differential thermal analysis of fat samples.

Mention of commercial names does not imply endorsement by the U. S. Department of Agriculture.