6 : 4

FAT HOLDING PROPERTIES OF PORK AND BEEF FAT - AS INFLUENCED BY COMMINUTION AND HEATING

TORNBERG, E. and PERSSON, K.

Swedish Meat Research Institute, POB 504,
S-244 00 Kävlinge, Sweden

SUMMARY

In this investigation the fat holding properties of fat raw material alone, when subjected to different degrees of comminution and subsequent heating to 75°C, have been studied. The fat sources used were pork back fat and beef fat from groin.

The instability (coalescence instability) of the fat raw material has been estimated by measuring the percentage of fat extracted by hexane. Additionally, the course of comminution and heating have been followed qualitatively under the light microscope.

An increasing degree of comminution [as revealed by microscopy of both pork back fat (raw) and beef groin fat (raw)] gives rise to a higher hexane extractability. Five different ways of disintegration have been studied. Among these the Moulinex mixer causes the highest degree of comminution, whereas dicing by hand with a knife causes the lowest. The former samples have a completely destroyed structure, the fat having smeared out all over the sample. With the same type of comminution, beef groin fat is more susceptible to disintegration, as revealed by hexane extraction, than pork back fat. This is suggested as originating from a less efficient chopping in the case of pork back fat compared to beef groin fat. This is further assumed to be related to the existence of more released fat from fat cells in the pork back fat, a phenomenon leading to reduced crack propagation.

Heating the disintegrated fatty tissues to 75°C causes further instability which, for all degrees of comminution, is more severe for beef groin fat than for pork back fat. The contraction of the connective tissue visible under the microscope on heating is, on average, greater for the beef groin fat than for the pork back fat. This could be one of the reasons for the fat holding capacity of the beef groin fat being lower than that of the pork back fat on heating.

INTRODUCTION

Fat separation in meat products such as hamburgers, sausages and liver paté causes quality problems. Therefore, in order to minimize such problems, it is of interest to study the fat holding properties of the fat raw material, alone and in the product. In this investigation we have restricted ourselves to studying the fat raw material alone as a first step in trying to elucidate the way in which fat is held in meat products.

The most commonly used fat sources in meat products are pork and beef fat originating from different anatomical locations. In this investigation we have chosen to study pork back fat and beef fat from groin. When this fatty tissue is disintegrated and heated during the production of the meat product the fat can be found in roughly two forms. Firstly, the fat remains in its natural fat cells as single cells or in aggregates. Secondly, the fat can be squeezed out of the cell and dispersed into the surrounding meat batter in the form of small droplets or larger fat pools.

The investigations presented so far in the literature on the fat holding properties of different fat raw materials in meat products have worked mainly along two lines of approach, i.e. either rendered fat (Swift et al, 1968 and Lee et al, 1981) or the fatty tissue have been studied (Townsend et al, 1971; Ackerman et al, 1971; van den Oord, 1973 and Evans & Ranken, 1975).

Using rendered fat (Swift et al, 1968) or soy plastic fats of different hardness (Lee et al, 1981) in meat emulsions of 22% fat content, both Swift et al and Lee et al have shown that the harder fats give rise to more stable emulsions, i.e. beef fat is generally better than pork fat in that respect. Swift et al, 1968 pointed out the importance of rate of release of oily fat as a determinant of emulsion stability, whereas Lee et al, 1981 observed the formation of fat channels under the microscope in uncooked emulsions for soft plastic fats. They suggested that such fat channel formations caused discontinuity of the protein matrix, thus leading to fat separation during cooking.

Comparing different fatty tissues (beef fat and pork fat) in frankfurters Townsend et al. 1971 observed that fat separation mainly occurred in those frankfurters containing beef fat, i.e. the other way around compared with rendered fat. Microscopic evaluation of these frankfurters (Ackerman et al, 1971) further demonstrated that no given dispersion of the fat consistently indicated fat separation or lack thereof. This is in accordance with the view of van den Oord and Visser, 1973 who argued that the ease by which fat cells become broken is likely to be the crucial factor with regard to the fat holding properties of sausages. Evans & Ranken, 1975, who were the first to investigate the cooking properties of the fatty tissue alone, attributed lipid loss on cooking not only to the number of fat cells broken but also to differences in the connective tissue present in the fatty tissue. They argued that harder fats like beef fat have weaker cell walls, which are more easily broken than those of softer fats, leading to higher fat losses.

In conclusion, the literature suggests that as long as the fat stays within the fat cells pork fat is the best choice amongst the fat raw materials. Whereas, as rendered fat, beef fat is preferable. The question is then how do different types of comminution and heating influence the proportion between the two forms of fat for both beef and pork fat? Furthermore, what fat instability does it cause? In this investigation we have tried to elucidate this problem by following qualitatively how the fatty tissue behaves under the light microscope during comminution and cooking. Moreover, the stability against fat separation (coalescence stability) has been followed in a quantified way. This has been carried out by measuring the percentage of fat extracted by hexane, as it has been shown for protein stabilised emulsions (Tornberg & Ediriweera, 1986) that the degree of hexane extraction of the emulsion is a reflection of the coalescence instability.

MATERIALS AND METHODS

Fatty tissue

The fatty tissues (fresh) used in the experiments were pork back fat and beef fat selected from the groin. Each specimen was a mixture of tissues from different animals. As assessed manually, the beef fat was harder than the pork fat.

Disintegration

After removing the rind and surrounding coatings the fatty tissue was disintegrated in five different ways: 1) The fat sample was diced by hand with a knife into 2 x 2 mm pieces. 2) and 3) The tissue material was comminuted in a 20 l Müller bowl chopper with six knives (2,800 rpm). Chopping was carried out for 30 and 90 seconds, respectively in 5 kg batches. Ice was

added during chopping (20% of total weight) to keep the temperature low. 4) Disintegration was performed once in a mincer with a 10 mm plate. 5) 200 g of fatty tissue was comminuted for one minute in a Moulinex mixer.

During disintegration the temperature was held at 2-4°C, except for the comminutions in the mincer and in the Moulinex, where the temperature rose to 13-15°C and 20-26°C, respectively. The fat samples were then stored at +4°C for further characterisation.

Heat treatment

About 6 g of the comminuted fat sample was weighed together with 9 g of distilled water in a glass tube. The glass tubes were heated in a water bath with a gradient of 1.5°C/min up to 75°C. The samples were then kept at 75°C for 3 min before cooling at +4°C.

Chemical analysis

The content of water (Nilsson, 1969), fat (NMR), crude protein (Kjeldahl, as modified by Nilsson, 1968) and hydroxyproline (Stegemann, 1958 as modified by Weber, 1973) were analysed for the fatty tissues. The connective tissue content was determined by the amount of hydroxyproline in accordance with the method of Wyler (1972).

Fat instability

Fat instability was estimated by measuring the fraction of fat extracted by hexane. It was carried out mainly according to the procedure outlined by Tinbergen and Olsman, 1979. Measurements were performed on the fat/water samples before and after heating in duplicate or triplicate.

Microscopy

Samples of the differently comminuted fatty tissues were frozen (-20°C) and mounted in a cryostat microtome (type TE, SLEE, London). Transverse sections, 25µm thick, were cut and mounted on microscope slides. For staining the sections Nile blue (0.4% water solution), for 2 min, was used. They were thereafter rinsed with distilled water and covered with cover glass. After staining, the fat became pink and the connective tissue blue. The sections were examined under a light microscope (Nikon Optiphot) at a magnification of 120x. Photographs were taken using Kodak Kodacolor 400 film.

To study the alterations in the structure during heating a heating table connected to the microscope with a temperature gradient of 1.5°C/min up to 80°C was used. Polarized light was used in the microscope to make it possible to study the crystalline regions showing birefringence. Photographs were taken on Kodak Ektachrome 160 EPT film at a magnification of 120x.

RESULTS AND DISCUSSION

In Table 1 the results of the chemical analysis for the two types of fatty tissues studied, i.e. pork back fat and beef groin fat, can be seen.

According to Table 1 there are no significant differences in water, fat and protein-content between the pork and beef fat studied. The connective tissue content, however, is significantly higher (2.3%) in the beef fat than in the pork back fat (1.9%).

Sample	Water content (%) x	s	Fat content (%) x	s	Protein content (%) x	s	Connective tissue content (%) x	s
Pork back fat (n=8)	10.3	± 1.8	85.9	± 1.5	3.4	± 1.0	1.9[a]	± 0.1
Beef groin fat (n=5)	10.2	± 0.7	86.5	± 0.8	3.1	± 0.6	2.3	± 0.2
Sign level							*	

a) n=4 $p \leq 0.05$: *

Table 1. Chemical analysis of the fatty tissues.

It is interesting to compare the chemical composition of the fatty tissues and their structure in the intact state. This is visualised in photograph A in Figures 1 and 2, respectively, where transverse sections of the fatty tissues raw, intact and comminuted in five different ways (Pictures B to F) are given. When the two photographs A in Figures 1 and 2 are compared it can be seen that the fat cells from the beef fat are on average larger than those of the pork back fat. Moreover, the connective tissue content of the former fat is higher than that of the latter, which suggests thicker cell walls of higher connective tissue content in beef groin fat than in pork back fat. This is an important observation which might explain some of the difference in hardness, as assessed manually. It further opposes the argument put forward by Evans & Ranken, 1975 that beef fat has weaker cell walls than pork fat.

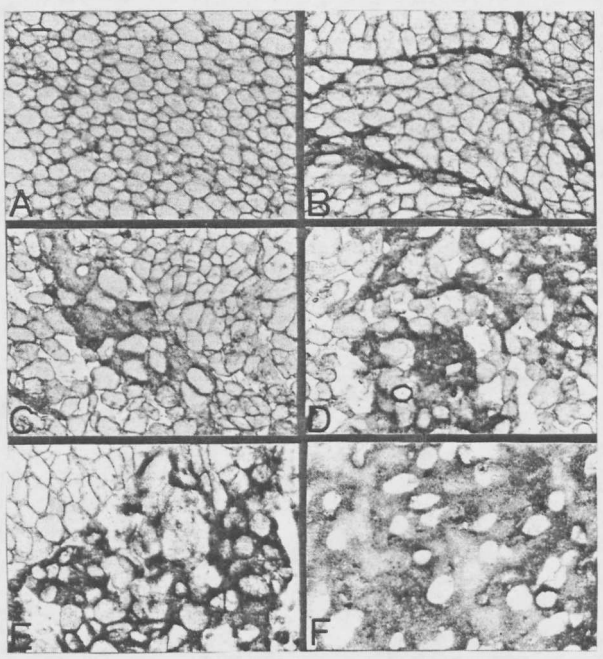

Figure 1. Transverse sections of pork back fat disintegrated in five different ways. Intact (A), diced by hand (B), chopped in a bowl chopper for 30 (C) and 90 (D) sec., minced in a mincing machine (E) and comminuted in a Moulinex mixer (F). ⟼ : 100 µm.

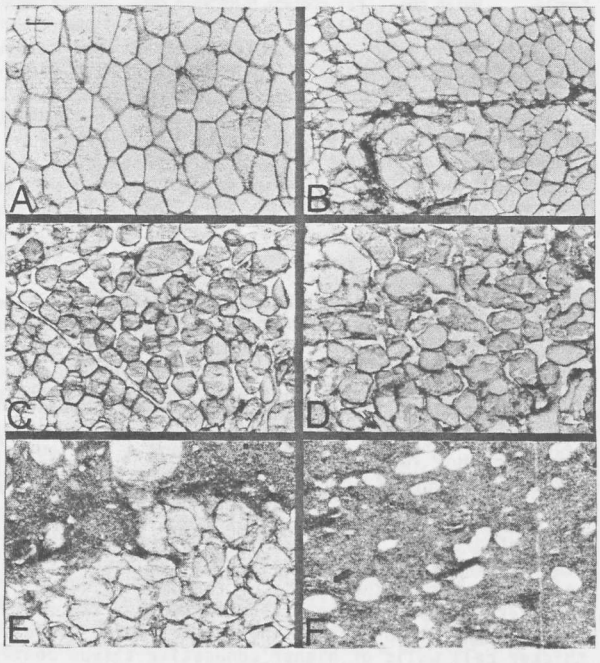

Figure 2. Transverse sections of beef groin fat disintegrated in five different ways. Symbols as described in the legend to Figure 1. ⟼ : 100 µm.

In pictures B to F the dark regions that can be seen are analogous to the fat that has been squeezed out of the fat cells. The intact fatty tissue (photographs A) do not show any fat of this kind. This released fat appears at a lower stage of comminution for pork back fat than for beef groin fat. This difference in behaviour for the two types of fat is most clearly seen in the samples that have been chopped in the bowl chopper (photographs C and D in Figures 1 and 2).

A comparison of the degree of crystallinity within the fat cells for the two types of fat studied can be made in Figure 3, where birefringence shows crystalline regions. According to this Figure pork back fat shows smaller crystalline regions than beef groin fat, which could be one of the reasons for the behaviour of the pork back fat, being more easily squeezed out of the cells.

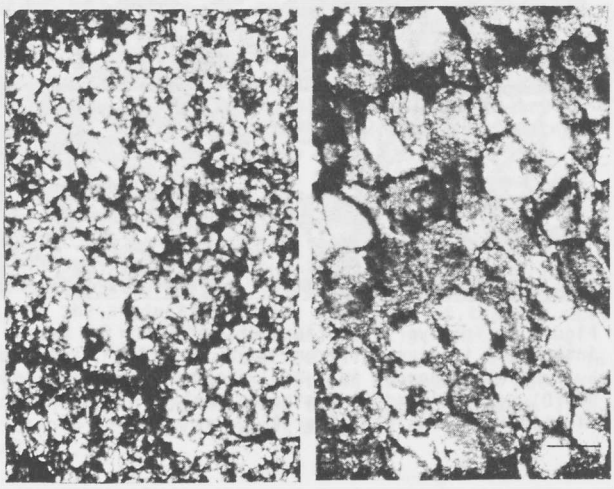

Figure 3. Transverse sections of pork back fat (A) and beef groin fat (B) raw intact immediately photographed after thin sectioning. Birefringence shows crystalline regions. ⟼: 100 µm.

It can further be noted for the chopped beef fat in comparison with pork fat that, although there is no released fat in the former, the disintegration has gone further with regard to the existence of more single fat cells. It is only in the minced sample (photograph E in Figure 1) where any substantial release of the beef fat from the cells can be found. This could be due to a higher shearing action in the mincer, compared to the bowl chopper, which will probably squeeze out the fat from the cells to a greater degree.

For the fatty tissues diced by hand (photographs B), fat outside the cells is only located where the knife has cut. From Figures 1 and 2 it can further be deduced that the fat cell integrity can always be seen somewhere within the sample for all the differently comminuted samples, except for those chopped in the Moulinex (photographs F). The latter samples have a more or less completely destroyed structure, the fat being smeared out all over the sample and some single fat cells dispersed into it.

Fat instability, as measured by hexane extractability, for the two types of fat at different disintegrations can be seen in Figures 4 and 5. When comparing these results with the structure of the fatty tissues, as seen in Figures 1 and 2, the following can be noted. For those samples giving rise to the least and the most released fat, i.e. those diced by hand and those chopped in the Moulinex mixer, the lowest and the highest hexane extractability is also found. This is observed both for the pork back fat and the beef groin fat. However, for the two samples chopped in the bowl chopper the degree of hexane extraction is substantially higher for the beef fat than for the pork fat, although the latter fat has more visible released fat. Moreover, those samples minced in the mincing machine have lower hexane extractability than those chopped for 90 s in the bowl chopper. Especially for the beef fat, the latter disintegration gives rise to a lower amount of released fat than the former.

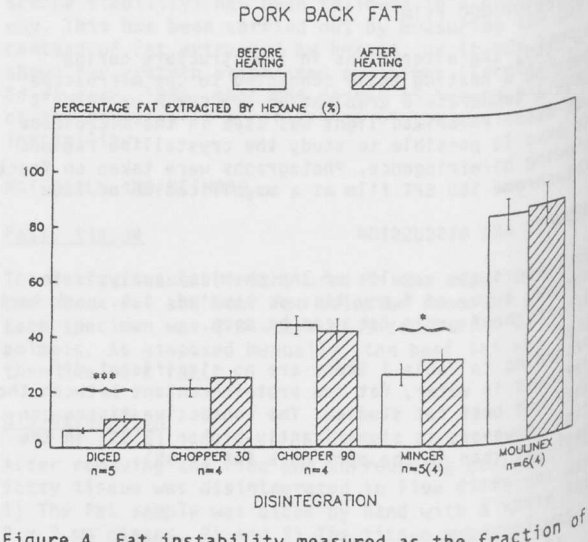

Figure 4. Fat instability measured as the fraction of fat extracted by hexane for pork back fat raw and heated and disintegrated in five different ways.

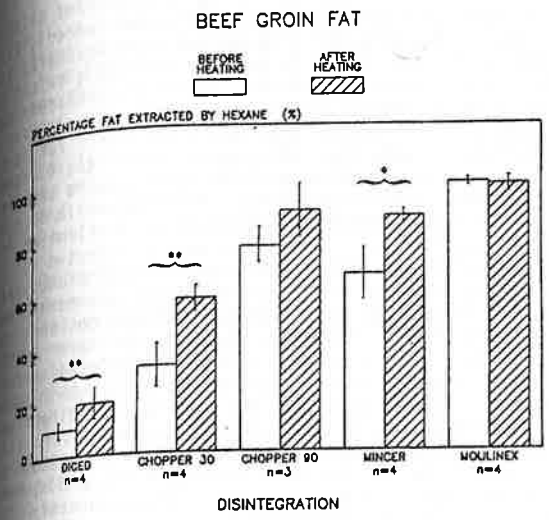

Figure 5. Fat instability measured as the fraction of fat extracted by hexane for beef groin fat raw and heated to 75°C and disintegrated in five different ways.

This seemingly contradictory behaviour might be explained by introducing some concepts of failure mechanics. The basic principles of the current theories of failure appearance are based on the likelihood of the propagation of cracks in the sample (Jowitt, 1979). Crack propagation can be very much reduced if the stress applied to the fat raw material during comminution is reduced by viscous dissipation of energy. Therefore, with an increasing amount of released fat the energy applied during comminution dissipates more and more as viscous energy (heat), leading to a less efficient chopping of the so far non-disintegrated fat material. This is in accordance with the observed behaviour of the pork back fat during comminution, i.e. being less comminuted but having more released fat.

We have also studied the fat instability after heating the differently comminuted fatty tissues to 75°C, the results of which can also be seen in Figures 4 and 5. In accordance with the investigations of Evans & Ranken, 1975 we too found the highest fat instability after cooking in the harder fat, which in our case is the beef groin fat. Furthermore, in this investigation we have found that heating causes, in general, further instability, which for all degrees of comminution (except for the chopping in the Moulinex) is more severe for beef groin fat than for pork back fat.

The course of heating for the differently comminuted samples has also been followed under the light microscope. In this paper only the course of heating for the least damaged sample of beef groin fat will be presented, i.e. the one diced by hand. In Figure 6 the structure of the beef groin fat can be followed at 23, 48, 60 and 80°C. In general, it was noted that the fat melting region, as observed by disappearing birefringence (seen at 23°C in Figure 6) occurs between 35 and 45°C. The most striking event, however, during heating of the fatty tissue is the contraction of the connective tissue, starting in general at 50-55°C and being most severe after 65°C. This is clearly seen for the beef fat sample in Figure 6 and this contraction of the connective tissue is generally greater for the beef fat than for the pork fat. This observation could be one of the reasons for the larger fat instability caused by heating in the beef groin fat, compared to the pork back fat. The contraction of the connective tissue does not occur, however, in the Moulinex sample, which could be due to a completed disintegrated connective tissue in those samples.

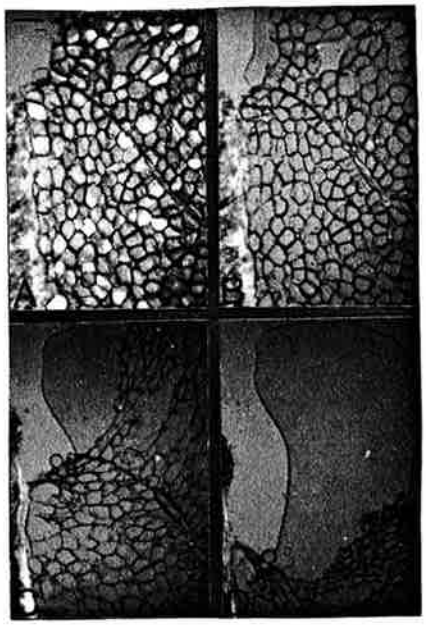

Figure 6. Transverse sections of beef groin fat diced by hand and heated to 23°C (A), 48°C (B), 60°C (C) and 80°C (D). ⟼: 100 µm.

REFERENCES

Ackerman, S.A., Swift, C.E., Carroll, R.J. & Townsend, W.E. (1971) J. Food Sci. 36, 266.

Evans, G.G. & Ranken, M.D. (1975) J. Fd Technol. 10, 63.

Jowitt, R. (1979) In "Food Texture and Rheology", P. Sherman (Ed.), p. 143. Academic Press, London.

Lee, C.M., Carroll, R.J. & Abdollahi, A. (1981) J. Food Sci., 46, 1789.

Nilsson, R. (1968) Swedish Meat Research Institute, Anal. Instr., No. 10.

Nilsson, R. (1969) Swedish Meat Research Institute, Anal. Instr., No. 6.

Stegemann, H. (1958) Hoppe-Seyler's Zeitschrift für Physiologische Chemie, 311, 41.

Swift, C.E., Townsend, W.E. & Witnauer, L.P. (1968) Food Technology 22, 117.

Tinbergen, B.J. & Olsman, W.J. (1979) J. Food Sci. 44, 693.

Tornberg, E. & Ediriweera, N. (1986) Food Emulsions and Foams, Ed. E. Dickinson p. 52.

Townsend, W.E., Ackerman, S.A., Witnauer, L.P., Palm, W.E. & Swift, C.E. (1971) J. Food Sci. 36, 261.

Weber, R. (1973) Technical Report No. 7, Genve, Technicon International Division SA.

Wyler, O.D. (1972) Fleischwirtschaft., 52, 42.

van den Oord, A.H.A. & Visser, P.R. (1973) Fleischwirtschaft 53, 1427.