A COMPARISION IN FAT HOLDING BETWEEN HAMBURGERS AND EMULSION SAUSAGES

E. TORNBERG, A. OLSSON and K. PERSSON

Swedish Meat Research Institute
P.O. Box 504, S-244 00 KÄVLINGE,
Sweden

INTRODUCTION

Hamburgers and emulsion sausages ("frankfurter type") are common minced meat products on the market. The former product is less comminuted than the latter and is usually just a mixture of ground meat, fat (usually beef fat) and seasoning. The procedure of manufacturing hamburger patties normally includes mincing, blending and forming, after which they are either frozen or fried and then frozen. Frankfurters and similar sausages are made by chopping meat with the addition of water and NaCl in a bowl chopper to a fine meat homogenate, in which usually pork fat is further dispersed and emulsified. Heat treatment of the stuffed sausage batter is performed in a smoke-house.

One of the most important features in the production of these two comminuted meat products is to achieve high stability, i.e. mainly prevent water and fat from separating out of the product. In this investigation we will focus on factors that prevent fat separation, i.e. promote fat holding, and this will be compared between the two types of products.

Fat in hamburgers and emulsion sausages is dispersed in a meat protein matrix. It can remain in its natural fat cells as single cells or in aggregates. Moreover, the fat can be squeezed out of the cells and be dispersed into the surrounding meat matrix in the form of small droplets, larger fat pools or fat channels. The question arises what is most beneficial with regard to fat holding in hamburgers and emulsion sausages? The properties of the fat (to remain in its natural fat cells or to be dispersed as fine droplets) or the properties of the embedding meat protein matrix?

In this investigation we have tried to elucidate this problem by following qualitatively and quantitatively (image analysis) the structural complexity of the two meat products under the light microscope. Moreover, the coalescence stability of the fat emulsion and/or the fat cell dispersion has been followed in a quantified way. This has been carried out by measuring the percentage of fat extracted by hexane. It has been shown for protein stabilised emulsions (Tornberg & Ediriweera, 1988) that the degree of hexane extraction of the emulsion is a reflection of coalescence instability. The fat holding of the meat product per se has been registered as fat loss during frying.

MATERIALS AND METHODS

Materials

The hamburger patties were made from 100% meat with 0.4% NaCl of the total weight added. The meat raw material was taken from different parts of the carcasses of young bulls, giving a range in fat content from 2 to 40% (w/w).

The usual ingredients for sausage making include nitrite salt, water, rindless pork fat and the meat raw material. This was prepared from equal portions of lean pork meat (23% fat) and beef meat (23% fat). The meat batters were manufactured with different fat contents, ranging from 18 to 35%. As the fat content was raised - the water content was lowered from 70 to 53% and the protein content varied from 7 to 12%. The salt level was kept at 1.9%.

Preparation of products

The meat for the hamburger patties was ground once through a 3 mm grinder plate and mixed with NaCl for 10 min at low speed in a Hobart mixer. A Hollymatic machine (model 54) was used to produce patties 100 mm in diameter, 10 mm thick and approximately 80 g in weight. The patties were frozen at -25°C and stored at the same temerature until analysis (approximately after two weeks).

Sausage batters were made in a 20 l Müller bowl chopper with 6 knives at a speed of 1400/2800 rpm. The batch sizes were 7 kg and they were made in duplicate. The ingredients were added and disintegrated at low speed in the chopper in the following order; meat (20 s), salt, ascorbic acid (10 s), water/ice (60 s) and fat (20 s). The batter was then comminuted for 130 s at high speed to a temperature of 9-15°C.

After preparation, the batter was stuffed into 22 mm collagen casings with a Vemag sausage filling machine (Robot 500, type 128) and hung on smoke-house trucks. The thermal processing plan consisted of a 15 min period at 60°C (50% RH), 5 min drying at 70°C (< 20% RH) followed by smoking for 30 min at 70°C (60% RH). The temperature was then raised to 75°C (100% RH) for 15 min followed by a water shower for 15 min and 30 min of cooling.

Chemical analysis

The content of water, fat, protein and hydroxyproline was analysed for all raw material in accordance with earlier studies (Fjelkner-Modig and Tornberg, 1986). The chemical composition of all meat batters was calculated according to the composition of their constituents. A pH meter was used to record the pH of all the batters (Orion 920).

Fat loss

Fat loss during frying (175°C until a centre temperature of about 70°C) was determined for the frozen beef patties and the smoked emulsion sausages. It was calculated by determining the total frying loss and the fat content of the products before and after frying. The fat loss was expressed as the percentage fat loss per fat content of the unfried product or as g fat/100 g hamburger.

Water loss

The percentage water loss after heating of the raw emulsion sausages, was mainly performed according to the net test by Hermansson and Luciano, 1982. Water loss during frying of the frozen beef patties was also determined.

Fat instability

The coalescence instability of the beef fat and the pork fat in the hamburgers and the emulsion sausages, respectively, was estimated by measuring the percentage of fat extracted by hexane. It was carried out mainly according to the procedure outlined by Tinbergen and Olsman, 1979 and modified by Tornberg & Ediriweera, 1988.

Microscopy

Samples of the sausages and the hamburgers, respectively, were cryosectioned. Thin sections, 12 µm thick, were mounted on microscope slides and stained with Nile blue as described earlier (Tornberg and Persson, 1987). Sometimes they were also stained with aniline blue and orange G according to Tornberg and Persson, 1988. The sections were examined under a light microscope (Nikon Optiphot) at a magnification of 27x and 134x, respectively. The Nile blue stained sections were exposed using UV light, which made the fat to fluoresce in a yellow colour, whereas other components did not. Photographs were taken with a camera (Olympus OM-2) using Kodak film (400 ASA). They were evaluated using an image analysing system LABEYE/3PC (Innovativ vision AB, Sweden) to calculate the fat droplet size distribution.

Instead of using the more frequently encountered volume/surface average diameter, d_{VS}, we have in this investigation used a surface/length average of the fat droplet size, i.e. $d_{AL} = 4ø_{A/L}$, where $ø_A$ is the area fraction of the fat (m^2/m^2), and L is the total circumference of all the fat droplets (m/m^2).

X, the mean free distance, has also been calculated, and is an estimate of the distance a fat globule can move on average before it touches a second globule. With the simplified assumption that d_{VS} can be replaced by d_{AL}, the following equation, derived by Walsta, 1969, has been used:

$x \sim 0.225\ d_{AL}\ (68.5/\rho G - 1)$

ρ = product density ~1.0,

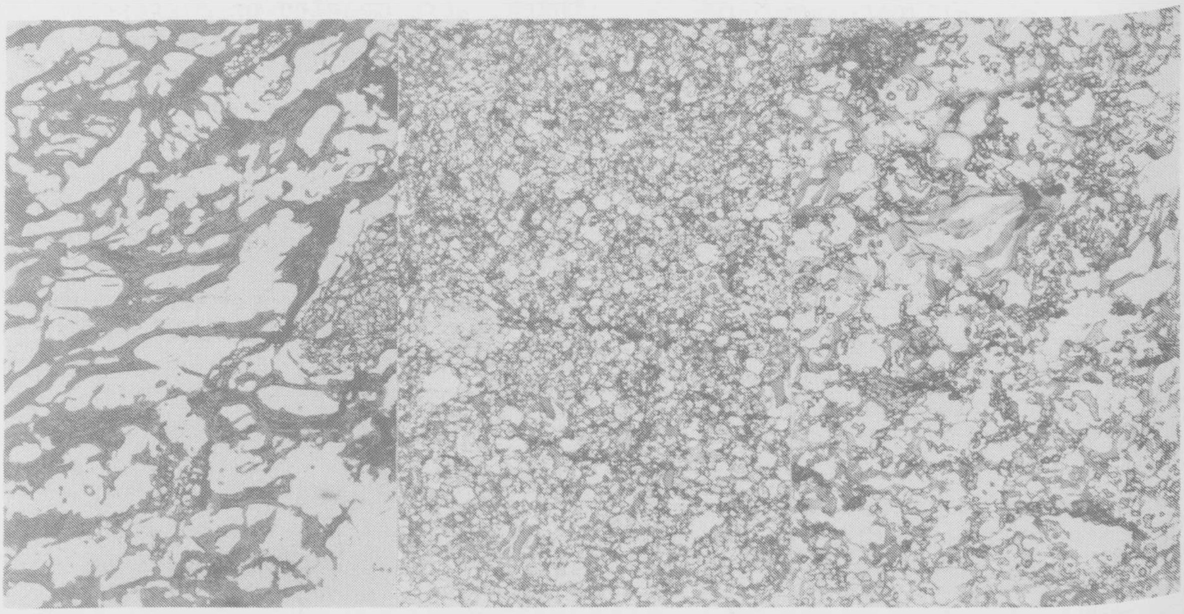
G = gravimetric fat percentage replaced by A = area fat percentage.

RESULTS

The microstructure

Examples of different meat protein matrices in hamburgers and emulsion sausages are evident in Figure 1. According to these micrographs of the tranverse sections of the two products, it can be seen that, for the hamburgers, the structure is built up by more or less intact meat fibres and fibre bundles. In the emulsion sausages, however, meat protein network formation constitutes the major part of the structure. Staining renders fibres and fibre bundles yellow and connective tissue and gelatin bluish, whereas fat cells and fat droplets remain unstained. Comparing the two micrographs B and C of the emulsion sausages in Figure 1, where the water/protein ratio is higher in the latter than in the former, a much denser protein network is found in B than in C.

Examples of the fat distribution of the two meat products can be seen in Figure 2. It can be deduced from the figure that the fat in the hamburgers is mostly in the form of fat cell aggregates and separate fat cells, and only to a minor extent in the form of small droplets. However, the fat in the emulsion sausages is mostly squeezed out of the cel



A B C

Figure 1. Thin sections of a hamburger (A) with a fat content of 14.2% and a water/protein ratio of 4.0 and two emulsion sausages (B and C) with a fat content of 32.3 and 24.0%, respectively, and water/protein ratios of 4.8 and 7.8, respectively. Staining was performed with anilin orange G. Magnification: 27X

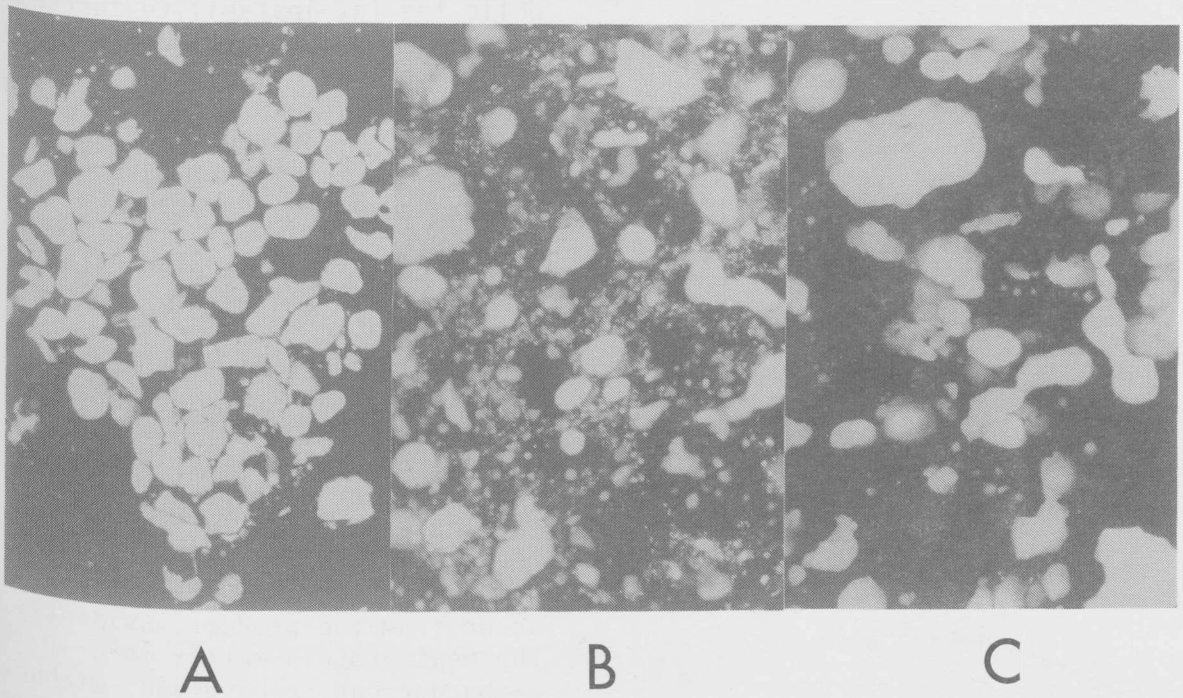


Figure 2. Thin sections of a hamburger (A) with a fat content of 13.7% and water/protein ratio of 4.2 and two emulsion sausages (B and C) with a fat content of 32.6 and 24.2%, respectively, and water/protein ratios of 5.4 and 8.8, respectively. The sections were stained with Nile blue and exposed to UV-light. Magnification: 134X.

exists in the form of small droplets and/or larger fat pools. Some fat cells are, though, still occurrent. It can be seen from micrographs B and C in Figure 2, representing emulsion sausages with low and high water/protein ratios, respectively, that the fat droplets in B are smaller and more evenly distributedin the protein matrix than in C. These observations suggest that comminution and disintegration of the fatty tissue is more efficient in a meat batter with a low water/protein ratio, as opposed to one with a high.

The size distribution of the fat particles in the hamburger patties and the emulsion sausages has been determined by image analysis. The surface/length average diameter d_{AL} has been estimated from 30 micrographs of hamburgers, varying in fat content from 2 to 30 % (w/w), and from 12 micrographs of emulsion sausages, varying in fat content from 24 to 33 % (w/w). The results of the analysis can be seen in Table 1.

It is evident from the table that the average diameter of the fat droplets is substantially larger in hamburgers than in emulsion sausages. The width of the size distribution(s) is also greater in hamburgers than in sausages.

A typical normal fat cell in adipose tissue from pork back fat is around 100 µm, whereas beef fat can contain fat cells as large as 200 µm (Tornberg and Persson, 1987). Therefore, with the average value of the pork fat droplets around 50 µm and the maximum value of d_{AL} at 55 µm in the emulsion sausage most of the fat can be considered to be squeezed out of the cell and disintegrated. Hamburgers, having only beef fat, also have

Table 1: Characteristics of fat droplet size distribution of hamburgers and emulsion sausages.

Meat product	n	d_{AL} (µm)	s(µm)	D_{AL}(max) (µm)	D_{AL}(min) (µm)
Hamburger	30	115.4	66.5	274.2	38.8
Emulsion sausage	12	46.3	10.4	55.1	30.5

disintegrated fat cells to a larger extent, but the maximum value of d_{AL} of 274 µm suggests that there also exist fat cell aggregates.

Fat losses and fat instability

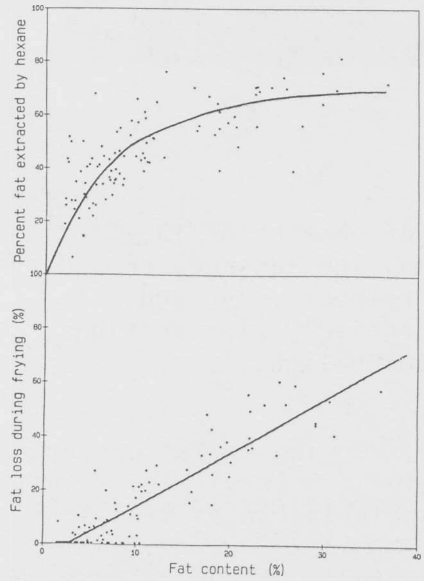


Figure 3. Fat loss during frying (lower diagram) and fat instability (upper diagram) for hamburgers of varying fat content.

In Figure 3 and 4, fat losses (percentage based on the initial fat content) during frying of hamburgers patties (raw) and emulsion sausages, can be compared. Moreover, in the figures the relationship between fat instability (percentage fat extracted by hexane) and fat content have been included for the two products, respectively.

For the hamburgers (Figure 3) fat loss on frying increases linearly with fat content ($r = 0.96^{**}$), while the fat instability increases exponentially with fat content. It starts to level off, however, at about 20 % fat. The extractability of hexane in hamburgers reaches, at most, 70-80 %, which is about the same value as Tornberg and Persson, 1987, obtained, when extracting fat from beef fat tissue alone, comminuted in a similar way.

One of the prerequisites for fat separation, when frying a meat product, is the possibility to transport fat from the inner to the outer part of the product. According to Figure 3 fat instability of about 20 % must first be achieved in a hamburger before any fat loss can occur from the product. Evidently, the meat protein matrix in a hamburger can, on average, withhold a fat content of about 4 %, having a fat instability of about 20 %, before fat separation occurs.

It is of further interest to compare the results from the fat instability measurements with the fat droplet size determinations in the hamburgers. There was, namely, a tendency for d_{AL} to increase with fat content, which could be one of the causes of the fat instability having the same dependence. Because Tornberg and Ediriweera, 1988, have shown that coalescence instability, as determined by the same method, increases with the fat droplet size of the protein stabilized emulsion.

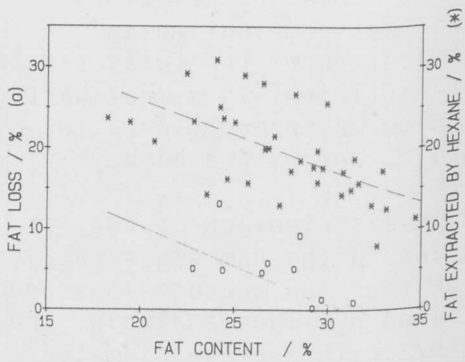


Figure 4. Fat loss during frying (o) and fat instability (*) for emulsion sausages of varying fat content.

However, when varying the fat content in emulsion sausages from 18 to 35 %, a negative relation was obtained in contrast to hamburgers, both for fat instability ($r = -0.61^{***}$) and for fat losses during frying ($r = -0.57$). This is clearly revealed in figure 4.

Firstly, we can observe that both fat losses during frying and fat instability are considerably less in emulsion sausages as compared to hamburgers. This is, in the case of fat instability, probably due to the smaller fat droplet size in emulsion sausages compared with hamburgers, which can be read off from Table 1. For the fat losses, however, the existence of an already formed meat protein matrix on cooking also comes into play; The denser the network - the more difficult to transport fat in order for separation to occur.

When comparing micrograph A (the hamburger) with the other micrographs of the emulsion sausages in Figure 1, it becomes evident that the meat protein matrix in hamburgers is much less dense than that in emulsion sausages. Together with higher fat instability, this gives rise to the higher fat losses occurring in hamburgers, compared with emulsion sausages.

The reason for the negative relationship obtained for emulsion sausages, as a function of fat content with regard to fat loss and fat instability, might be dependent on the following. When the fat content is raised in the sausages, as well as in the hamburgers, the water/protein ratio is lowered from 8.0 to 5.0 in the sausages and from 5.0 to 3.5 in the hamburgers, respectively. The difference that this creates in an emulsion sausage, with regard to meat protein network and fat droplet size, can be envisaged in Figure 1 and 2, when comparing micrographs B and C, respectively. In micrograph B, in Figure 2, representing the sausage with the higher fat content and the lower water/protein ratio, the fat is more finely dispersed than in C. This might be the cause of the higher fat stability (lower degree of fat extracted by hexane) at larger fat content. Fat losses during frying are also reduced with higher fat content. Besides the lower fat instability at higher fat content, it might also depend on the denser protein network formed, when the water/protein ratio is low. This can be seen in Figure 1, where the pore size of the protein network at high fat content (micrograph B) is substantially smaller than in migrograph C (low fat content).

DISCUSSION

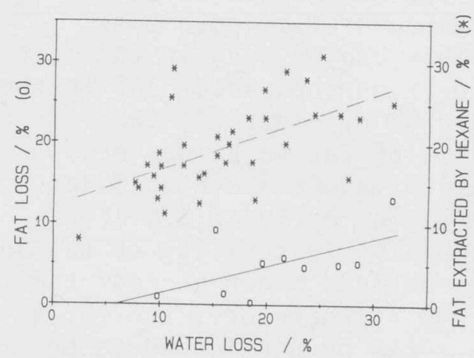


Figure 5. Fat loss during frying (o) and fat instability (*) for emulsion sausages as a function of water loss.

The above described mechanisms for fat holding in emulsion sausages, do not seem to appear for hamburgers, even though an increase in fat content for hamburgers gives rise to a lower water/protein ratio. This difference in behaviour between hamburgers and emulsion sausages is further confirmed by the fact that water loss (reflecting the properties of the protein matrix) does not relate to fat loss in hamburgers ($r = 0.007$).This is, however,the case for emulsion sausages both with regard to fat instability ($r = 0.60^{***}$) and fat loss ($r = 0.59$). This can be seen in Figure 5. Evidently, according to Figure 5, the dense protein network formed in an emulsion sausage efficient in holding water can also be beneficial with regard to fat stability. This suggests that the meat protein matrix formed in emulsion sausages at low water/protein ratios can prevent fat globules from coalescing although the probability of encounter between fat droplets is greater, due to higher fat content and finer droplets. This finally results in better fat stability in emulsion sausages under these circumstances.

What is then most crucial for fat holding in hamburgers? If the fat losses during frying are expressed as a percentage based on the weight of the hamburgers instead of the fat content, the dependence on fat content is quadratic instead of linear. This can be seen in the left diagram of Figure 6. According to the upper diagram of Figure 3, the instability of fat in hamburgers reaches high values above 30 %, at fat contents as early as 5 %. For comparison, the instability of fat in emulsion sausages never exceeds the value of 30 %. Therefore, the fat in hamburgers can be considered to be relatively unstable. We, therefore, make the assumption that the limiting factor, with regard to fat separation in hamburgers, is the transport of the fat from the inner to the outer part of the product. The probability of this mechanism occurring is higher - the more frequent the encounter between fat droplets and fat cells. Therefore, we have calculated the mean free distance, x, between fat droplets as a function of the fat content for hamburgers. The result can be seen in the right diagram of Figure 6. Our assumptions seem to be well justified, because the mean free distance diminishes in the same quadratic way with fat content ($r = 0.91^{***}$), as the fat loss increases.

CONCLUSIONS

Fat separation in meat products is mainly dependent on two factors:
I. The instability of the fat itself.
II. The possibility to transfer the fat from the inner to the outer parts of the product.

I. The instability of the fat is highly dependent on a) the dispersity of the fat, i.e. the fat droplet size distribution and b) the protective properties of the surrounding fat droplet membrane against coalescence. This membrane can either be the original fat cell membrane in the fat cell or an emulsified protein layer

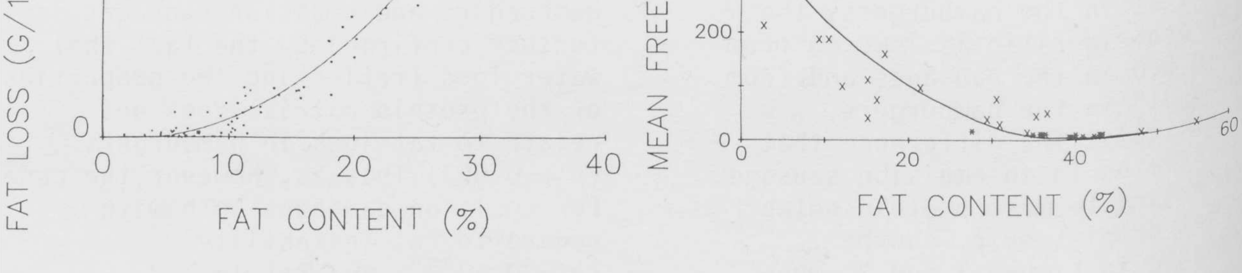


Figure 6. Fat loss during frying (g/100g hamburger) for hamburgers (left) and the mean free distance (μm) between fat globules/fat cells in hamburgers (right) as a function of the fat content.

and/or a dense protein network entrapping the fat globules.

II. The possibility to transfer fat out of the product is enhanced with high probability of encounter between fat droplets, resulting in larger fat pools and even fat channels. This is in turn dependent on a) the density of the protein meat matrix; The higher - the more prevented the fat transport b) the instability of the fat influenced by all the above enumerated factors.

In this investigation, where for hamburgers and emulsion sausages the dispersity of the fat (image analysis of micrographs), the coalescence instability of the fat (degree of fat extracted by hexane) and fat losses during frying have been investigated, the following can be stated:

For hamburgers, where the fat is relatively unstable and the raw meat protein matrix is coarse, the probability of encounter between fat droplets seems to be the most dominant factor in controlling fat release during frying. Therefore a positive, quadratic relationship is obtained between fat losses and fat content, as the mean free distance between fat droplets progressively diminishes in the same way.

For emulsion sausages, where the fat is relatively stable and the fixed meat protein matrix is comparitively dense, the properties of the fat and the protein matrix come more into play. In particular, the meat protein matrix seems to be important as both fat instability and fat loss correlate with water loss (reflecting the properties of the protein network), while this is not the case for hamburgers.

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