EFFECT OF PROCESSING CONDITIONS ON MICROSTRUCTURE AND FUNCTIONAL PROPERTIES OF COMMINUTED MEAT BATTERS

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INTRODUCTION

THE QUALITY of comminuted meat products are highly dependent on processing conditions such as time and temperature as well as on the design of the equipment used. Several studies have been made on the effect of processing conditions in a bowl chopper on various properties. Hansen (1960), Helmer and Saffle (1963), and Ackerman et al. (1971) showed the effect of final process temperature on the microstructure of batters. The fat and water release after heat treatment were studied as a function of chopping parameters such as temperature and speed by Townsend et al. (1968; 1971) Schut and Brouwer (1975), and Brown and Toledo (1975). So far very little has been published on the effect of equipment design on the microstructure and functional properties of finely comminuted meat batters. Knowledge in this field is badly needed since there is an increasing change-over from batch to continuous production of meat batters.

The aim of this paper is to give some examples of the effect of processing in three kinds of equipment on a pilot-plant scale. The functional properties presented here include fat and water release before and after heat treatment. The microstructure was evaluated by light microscopy.

MATERIALS AND METHODS

THE FORMULA consisted of 32.8% lean beef meat, 31.1% pork back fat, 34.1% water, and 2.0% salt or approximately 8% protein, 27% fat, and 62% water.

The batters were prepared in the following equipment

1. A bowl chopper with 6 knives, a motor speed of 1500/3000 rpm and a capacity of 25 l (Rohwer-Kolbe).
2. A Stephan Universal Machine UMM-SK2E with 6 knives, a motor speed of 1500/3000 rpm, and a capacity of 25 l.
3. A Stephan Microcut MCH-D30 with a twin cutting system and a capacity of ca 2000 kg/h. The two cutting heads could be adjusted to slit widths of 1.5 to 0.2 mm.

Frozen meat and fat were slowly thawed at 0°C and precut into cubes. With the bowl chopper or universal machine operating at low speed the ingredients were added in the following order: meat, salt, water, and fat. The temperature before chopping at high speed was 4 to 6°C. The raw materials for batters to be produced in the Microcut were blended and coarsely communited in the bowl chopper as described above. The size of the batches was ca. 15 kg.

Fat and water release was measured before and after heat treatment by two different methods. For the raw meat batters 20 g was placed in centrifuge tubes, tempered at 30°C, and centrifuged at 15000 xg for 15 min. Released fat and water was measured in ml/100 g of batter. Four replicas were made.

In the heat stability test 10 g of batter was placed in graded tubes, centrifuged gently to deaerate and heated at 75°C for 30 min. The meat plug was removed and released fat and water measured in ml/100 g of batter. Six replicas were made. The standard deviation for both tests was $\leq$ 1.0%.

For the light-microscopy examination meat batter was fixed in 4% formalin for at least 15 h. Small pieces were then frozen in liquid nitrogen and cryosectioned at -30°C to a thickness of 10 μm. The sections were either investigated directly under polarized light or stained for protein, collagen, and fat. Sudan Black B was used as a fat stain.

RESULTS AND DISCUSSION

IN A BOWL chopper the knives are rotating perpendicular to the bowl. The distance between the cutting edge and the bowl is small (ca 1 mm). During chopping optimal conditions are known to exist when the batter has reached a temperature of 14-16°C. Figure 1 shows the effect of final batter temperature on fat and water release after heat treatment. The fat release was minimal in the range of 12-21°C and increased markedly at temperatures above 21°C. The water release was less dependent on processing conditions. Similar trends were obtained also when other formulas were used. It is not possible to make a clear distinction between the effect of chopping temperature and time from this type of test.

The results shown in Figure 1 were caused both by chopping and heat treatment. As structural changes caused by heating were substantial, it was of interest to measure the properties of unheated batters. Figure 2 shows the fat and water releases as a function of final process temperature. As can be seen, the water release decreased with prolonged chopping up to a temperature of 21°C, whereafter no changes were observed. The fat release, on the other hand, remained unchanged up to 21°C, whereafter it increased markedly.

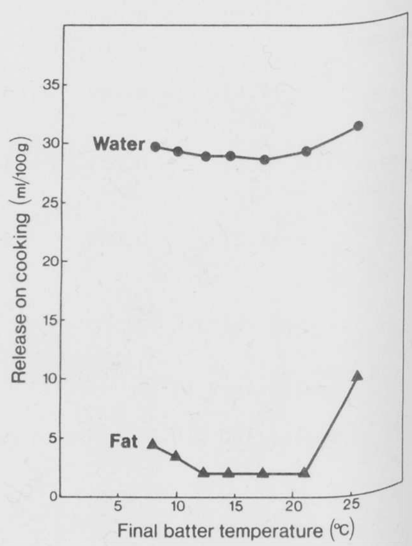

Figure 1. Water and fat release after heat treatment as a function of final batter temperature in the bowl chopper.

The distribution of fat in the meat matrix is considered an important event during chopping. Anisotropic fat and cell membranes have strong birefringent properties. Intact muscle fibers have weak birefringent properties whereas the comminuted meat matrix and amorphous fat have none. Figures 3 and 4 are micrographs taken in polarized light of the batters chopped to 14.5^{o}C and 26^{o}C, respectively. At 14.5^{o}C fat is visible both in fat cells and as fine particles distributed throughout the invisible meat protein matrix. At 26^{o}C, overprocessing has caused phase separation and most of the fat is in the form of large fat pools, although some intact fat cells are still present. No muscle fibers can be seen. The results are in close agreement with those obtained by specific staining of fat and protein (Hansen, 1960; Hermansson, 1980).

In contrast to those of the bowl chopper the knives in the "Universal machine" are mounted on a vertical shaft in the bottom of the bowl and rotate horizontally. There is a long distance between the cutting edge and the bowl wall of, ca 5 cm. The condition of the knives was expected to be of importance for the efficiency of the process. If the knifes are not sharp enough, the tissues will be torn apart rather than properly cut. A comparison was made between two types of knives. Type A had a normal, smooth cutting edge, whereas type B had a wave cut edge. From Figure 5 it can be seen that under- and overchopping caused a much higher fat release when knives of type B were used. In the optimal temperature range the difference in fat release was negligible and equal to that obtained in the bowl chopper. The water release was higher when type B knives were used throughout the process. The results show that the quality and design of the cutting device are of extreme importance.

Very little is as yet known about the optimal choice of criteria for continuous production of meat batters. Several types of equipment with different cutting systems exist. In this study a Stephan Microcut MCH-D30 with a twin cutting system was used. Functional properties and microstructure were investigated as a function of the slit widths of the two cutting heads. The following combinations were tested 1.5-0.9, 1.3-0.9, 1.3-0.7, 0.0-0.7, 0.9-0.5, and 0.5-0.2 mm. The "Microcut" process was regarded as a unit process for emulsification. As such, it was compared with the bowl chopper, and additional blending and coarse comminution were made in the bowl chopper under exactly the same conditions as described above. This means that optimal conditions for bowl chopping were used, which are not necessarily the best conditions for the continuous process.

Fat and water release after heat treatment as a function of slit widths is shown in Figure 6. Final batter temperatures are written within brackets. Neither the water nor the fat release seems to be dependent on the slit widths. Both the fat and water release shown in Figure 6 is higher than those of the batters produced in

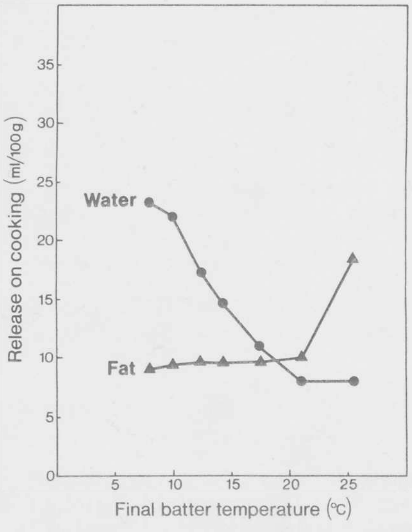

Figure 2. Water and fat release of raw batter after centrifugation at 15.000 xg as a function of final batter temperature in the bowl chopper.

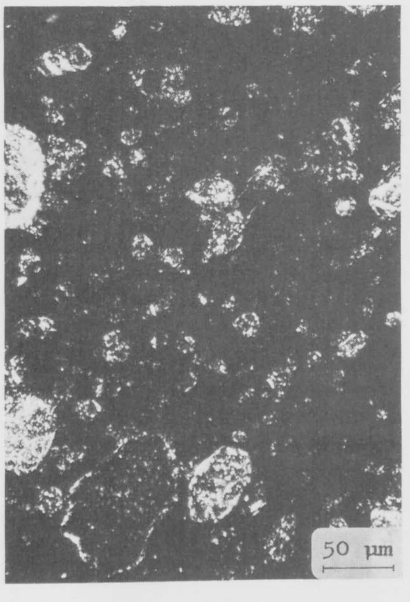

Figure 3. Batter chopped to 14.5^{o}C in the bowl chopper viewed by polarized light.

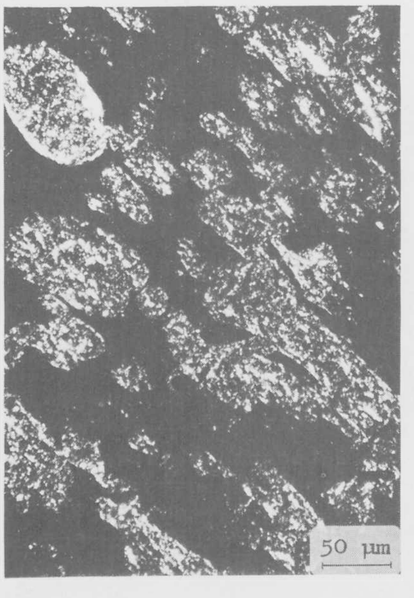

Figure 4. Batter chopped to 26^{o}C in the bowl chopper viewed by polarized light.

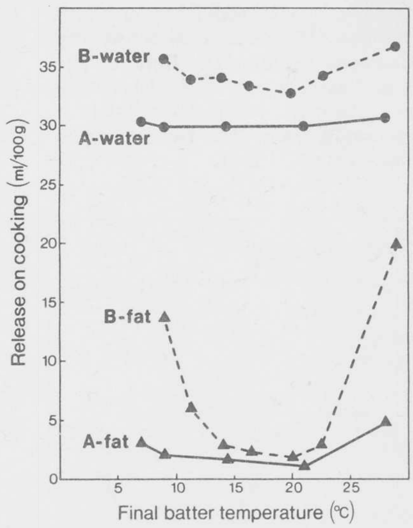

Figure 5. Water and fat release after heat treatment of batters chopped with two different types of knifes in the "Universal Machine" as a function of final batter temperature.

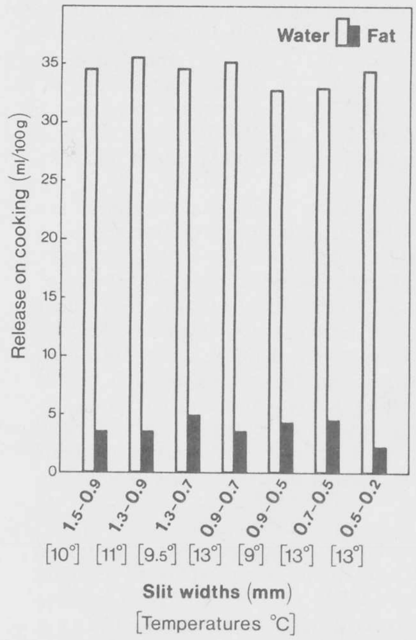

Figure 6. Water and fat release after heat treatment at various slit width combinations in the Sephan Microcut.

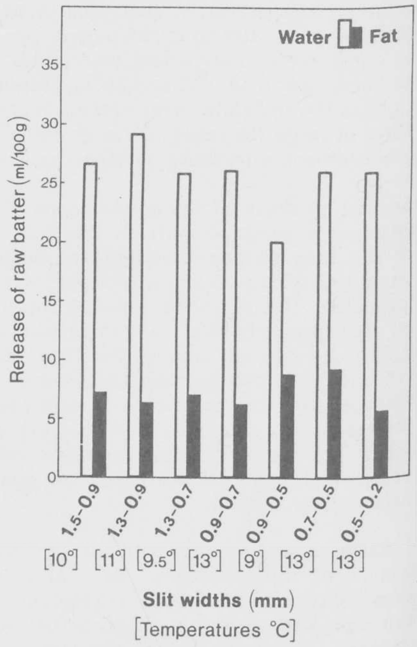

Figure 7. Water and fat release of raw batters at various slit width combinations in the Sephan Microcut.

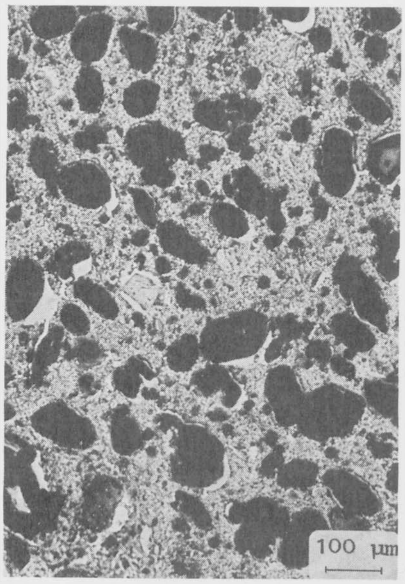

Figure 8. Batter chopped to 14.5°C in the bowl chopper after specific staining of fat with Sudan Black B.

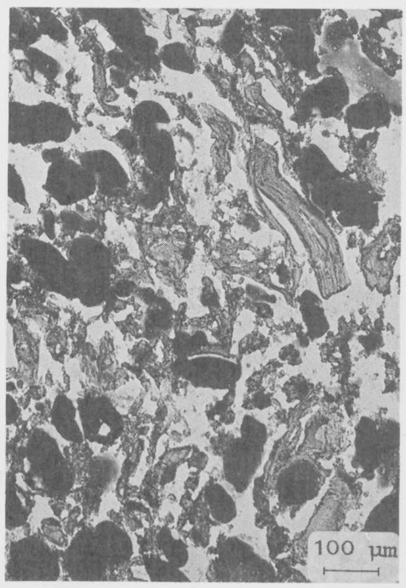

Figure 9. Batter produced in the Stephan Microcut with the slit width combination 1.3-0.7 mm.

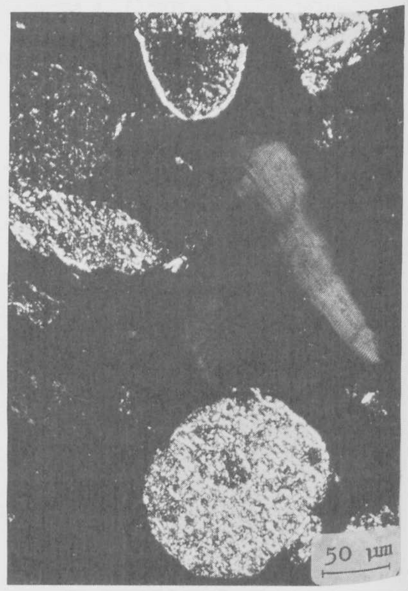

Figure 10. Batter produced in the Stephan Microcut with the slit width combination 0.7-0.5 mm viewed by polarized light

the bowl chopper. When the batter was run a second time through the Microcut machine, the water release decreased for all combinations by on the average 2%. The fat release increased for the combinations 1.5-0.9, 1.3-0.9, 1.3-0.7, 0.9-0.7 by on the average 2% and decreased for the combinations 0.9-0.5, 0.7-0.5, 0.5-0.2 by on the average 2%.

Figure 7 shows the fat and water release of the raw batters before heat treatment as a function of the various slit width combinations. The fat and water release seems to be independent of slit width or final temperature also before heat treatment.

The fat release was lower and the water release was higher than the corresponding data obtained for bowl chopping (Figure 2). The results indicate that the state of the meat protein matrix was not optimal after processing in the Microcut Machine and that a proper network was not formed upon heating. This hypothesis is confirmed by the micrographs shown in Figures 8 and 9. The sections have been specifically stained for fat and protein in this case, and the fat shows up dark in the figures. Figure 8 is a micrograph of the batter produced in the bowl chopper with a final temperature of 14.5°C. In this batter the fat is evenly distributed in a continuous meat matrix. Apart from fat cells, a great number of small fat particles can be seen. Figure 9 is a micrograph of the batter produced in the Microcut with slit widhts of 1.3-0.7 mm. In this batter the muscle tissues seem torn apart, and there is a low degree of coherent meat protein matrix. A large number of fat cells are present.

Small fat particles with birefringent properties were sparse in the batters produced in the Microcut compared with those of the same composition made in the bowl chopper. This is illustrated by Figure 10, which is a micrograph of the batter produced with slit widths of 0.7-0.5 mm. Almost no small particles can be seen, but intact muscle fibers (M) with birefringent properties are still present.

Under the test conditions no coherent meat matrix was formed, and the fat was not "emulsified" in the Microcut. However, the results may be quite different in a large-scale operation. For example, flow parameters such as shear forces and pressures are believed to be of importance for the efficiency of the cutting system and need to be further studied.

CONCLUSIONS

THIS INVESTIGATION points out the importance of parameters such as equipment design and process temperatures on the functional properties and microstructure of meat batters. Thus in order to control industrial processes, one has to consider these parameters.

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