WATER AND SALT TRANSFERS ANALYSIS IN DRYING OF SAUSAGES

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SUMMARY

Two batches of sausages were prepared from pork meat and dried for several weeks. During the experiments the drying conditions were recorded continuously and the evolution of the following variables was measured : (1) Sausages diameter and weight loss to evaluate the shrinkage and drying rate, respectively and (2) profiles of water and salt contents to investigate the internal transfers. In a separate experiment the mass transfer coefficient at the interface solid-air, to which the evaporation rate is proportional, was measured for air velocities ranging from 0.15 to 0.45 m/s and for various lengths and diameters of the sausages .

The shrinkage was found to be approximately proportional to the water loss. A migration of salt from the outermost to the innermost part was observed. The gradients of moisture content were steep in the first 10 mm close to the surface, while they were almost flat in the core part, indicating a very low effective water diffusivity. The formation of a dry crust in one experiment corresponded to the steepest moisture content gradients and to a dramatic decrease of the drying rate.

INTRODUCTION

In France, the production of dry sausages is about 90 000 tonnes a year. This product varies widely in size (0.2 to 4 kg) and composition, leading to various textures and flavours. However the fabrication always involves the following successive operations : grinding of lean meat and fat, mixing with additives, stuffing in casings and drying. This latter process is costly, because it lasts several weeks, and greatly affects the quality. The problems which can occurred during the fabrication have been recapitulated by Sirami (1990) ; a lack of control of the drying conditions, which are usually adjusted by an operator using empirical rules, is a major cause of bad quality. The rate of water evaporation at the surface must balance the migration of water from inside the sausage to the surface. When the evaporation rate is too low undesirable moulds can develop ; on the contrary, the formation of a dry crust prevents water loss and affects badly flavour and texture.

The aim of this study was to gather data relative to mass transfers in order to lay the basis for further technical developments that could prevent the occurrence of a dry crust.

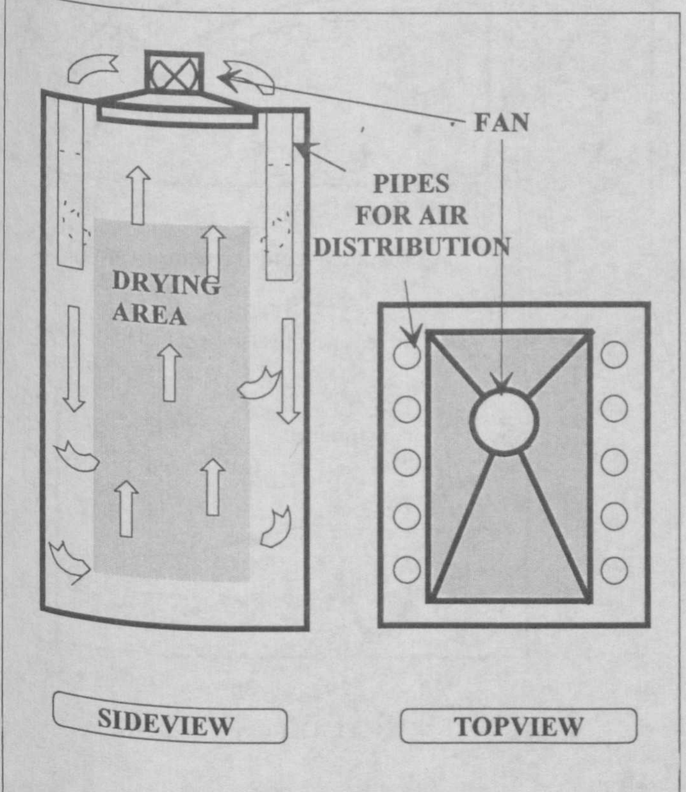

Figure 1 : diagram of the dryer

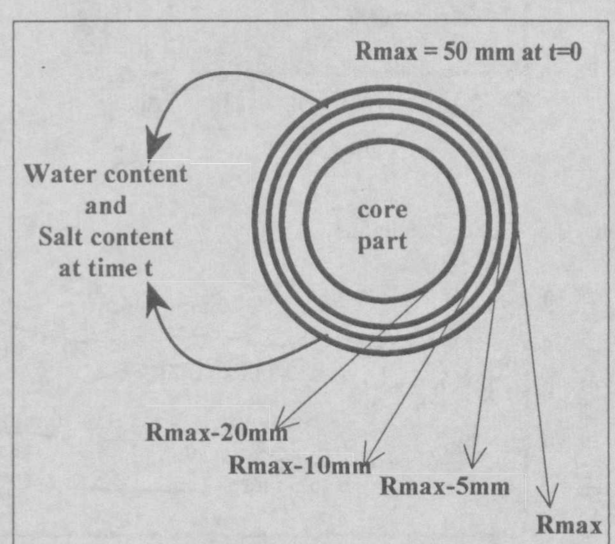

Figure 2 : Preparation of the samples for analysis

MATERIAL AND METHODS

Two experiments were carried out. For each experiment 40 kg of lean pork meat and 10 kg of fat were roughly cut into small cub chilled to -2°C and grinded using a plate with holes 6 mm in diameter. Then, the grinded meat was mixed under vacuum with the additiv in exp.A 1.4 kg salt, 150 g pepper, 150 g dextrose and a starter (50 % *Lactobacillus Sake* + 50 % *Staphylococcus Xilosus*) were add while in exp.B neither sugar nor starter was used. The preparation was stuffed into collagen casings 10 cm in diameter in order to ob sausages of 2 ± 0.015 kg. The sausages were left at 10°C for 18 hours and hung into the dryer.

The dryer is sketched in figure 1. A fan blew the air into the drying cell through lateral pipes of different lengths ; a previous w related to the air circulation have shown a spatial variation of the air velocity in the range 0.05 to 0.35 m/s (Daudin and Kondjoyan, 1991 The relative humidity (RH) was maintained within a maximum and a minimum ; these values were changed every day by the operato adjust the drying conditions. When the RH reached the lower threshold the fan stopped automatically, and it started again when the reached the higher one as a result of moisture loss from the sausages.

Every 2 or 3 days all the sausages were weighed to calculate the average drying yield and one sausage was randomly chosen determine the water and salt profiles. The procedure followed during this latter operation is illustrated in figure 2 : the sausage was cut i slices 2 cm height which were themselves cut into concentric rings of different thicknesses. Each ring was grinded ; 5 g were dried up 12 105°C to get the water content and 10 g were used to measure the sodium chloride content using the Chlorodimeter S100 (Bioarrow).

The rate of water evaporation is proportional to the mass transfer coefficient at the interface solid/air which depends on both velocity and product shape and size. A psychrometric method based on weight loss and surface temperatures measurements during the ste state of drying (Kondjoyan and Daudin, 1990) was applied on plaster mouldings of sausages to determine the average mass tran coefficient in various situations. The air flew along the main axis of the mouldings which diameters and lengths were in the ranges 4.2 to cm and 12.6 to 55.2 cm, respectively. The air velocity was varied from 0.15 to 0.43 m/s.

RESULTS AND DISCUSSION

The results of experiments A and B are presented in figures 3 an 4, respectively.

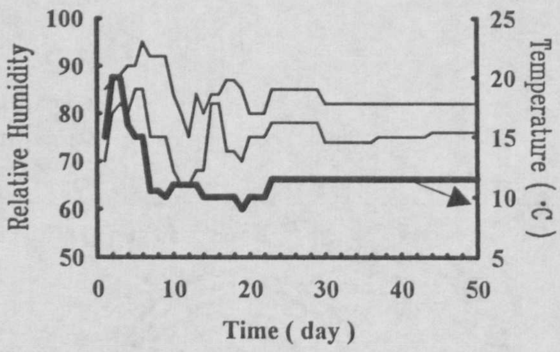

Figure 3.a : Drying conditions

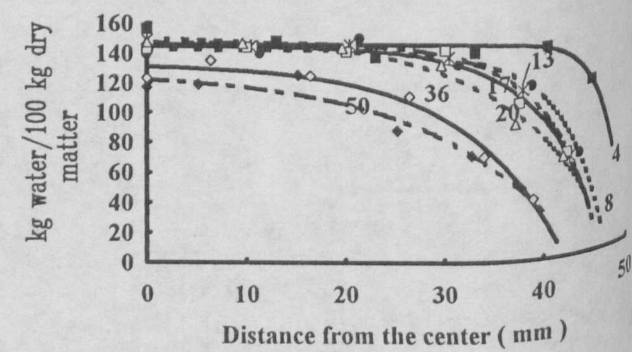

Figure 3.c : Water content profiles (figures = day of analysis)

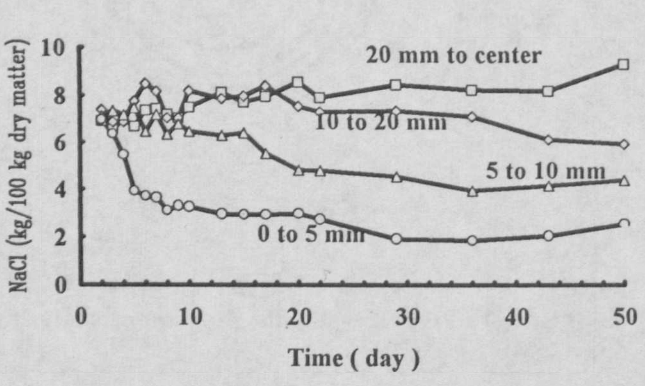

Figure 3.b : Evolution of the salt content in the different rings (distances from the center).

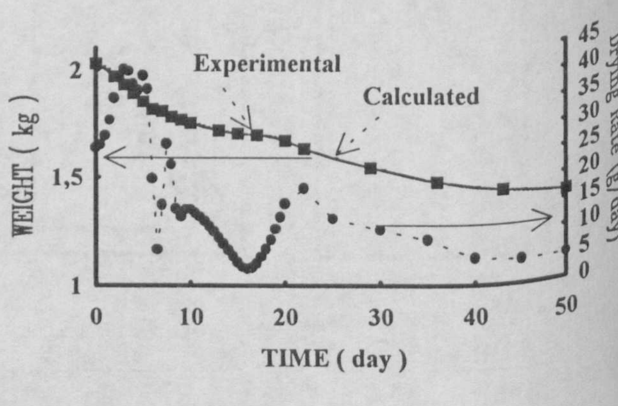

Figure 3.d : Drying kinetics.

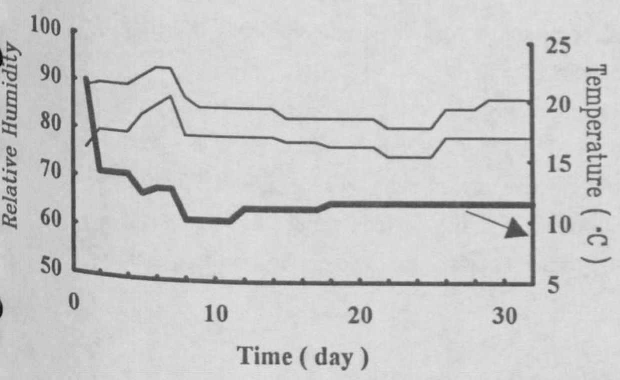

Figure 4.a : Drying conditions

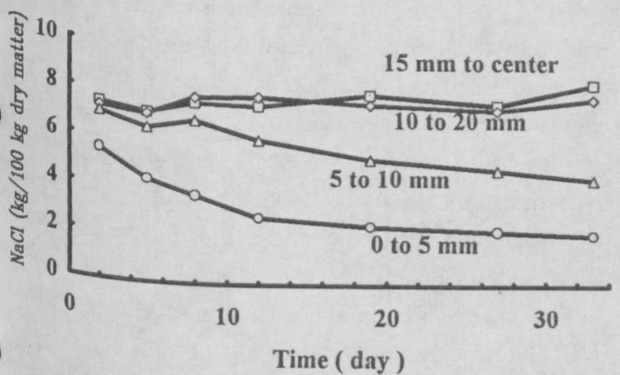

Figure 4.b : Evolution of the salt content in the different rings (distances from the center).

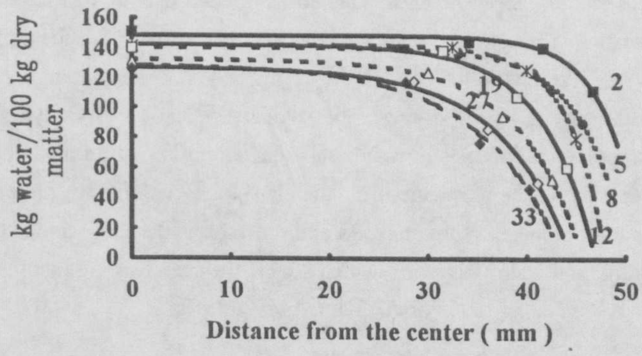

Figure 4.c : Water content profiles (figures = day of analysis)

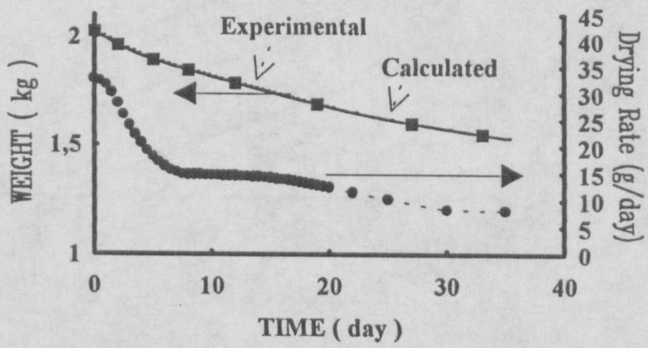

Figure 4.d : Drying kinetics.

The records of the drying conditions are given in fig.3-4.a. The air temperature was fixed at 22°C to promote fermentation during the first phase of ripening; it was reduced to 11.5°C in a few days and kept at this level. It is well known in practice, and was demonstrated by Stiebing an Rodel (1990), that the pH drop facilitate the release of water. Thus, in exp A where a starter was added the RH was lowered from the 6th to the 14th day.

Fig.3-4.b show the variation of the salt content with time in the different rings : 0 to 0.5 cm (R1), 0.5 to 1 cm (R2), 1 to 2 cm (R3) from the surface and the core part (R4). To avoid difficulties in the analysis because of the water content depletion, the salt content was expressed in % on a dry basis (kg of salt/100 kg of dry matter). The two experiments revealed a migration of salt from R1 to R4. The salt content in the core part increased from 7.25 to more than 8 %. In R1, which is subjected to the highest rate of water removal, the salt content dropped to about 2 % in 15 days. In exp.A which lasted 7 weeks R2 and R3 exhibited similar behaviour than R1 but the decrease was smaller and delayed.

The evolution of the water content profiles are given in fig.3-4.c. The water content at the middle of a ring was considered to be equal to the average value measured in the whole ring. The shrinking (reduction in the diameter) was taken into account by assuming that the loss in volume corresponded exactly to the water loss ; this assumption was in good agreement with the evolution of the diameters measured during experiment B. The profiles were calculated by fitting the experimental values with:

Water Content = A (1+B exp((5 - r) C))

where A,B,C are constants and r the distance from the centre in cm.

Stiebing and Rodel (1990) reported a water loss 2 times higher in the edge part (0 to 1.6 cm from the surface) than in the core part of sausages 5.5 cm in diameter after 7 days of drying. This figure is in agreement with the present results when the average of R1+R2+R3 is compared to R4, but the profiles give more information. In both experiments the gradients in moisture content were very steep in the first 10 mm close to the surface while they were almost flat in the core part. This indicates, as it has been already suggested by Lenges et al (1973) that the effective water diffusivity is very low in meat products and probably decreases with the water content. The value of the water content extrapolated at the surface is not accurate, even in exp.A where 6 rings instead of 4 were analysed ; nevertheless it is clear that it dropped during the first 8 days and stayed at about 0.2 kg water/kg dry matter.

In exp.B, the water content in the different rings, and consequently the profiles varied regularly. On the contrary, in exp.A, the water content in R1 was constant between the 8th and the 20th day. From the 13th day the water content in R2 decreased significantly leading to less and less steep profiles. This corresponded exactly to the observations of the operator who detected empirically the occurrence of a dr crust the 13th day and increased the RH, as it usual in practice, to stop the phenomenon.

Figures 3-4.d present the drying kinetics. The average value of the sausages weight were considered ; this was justify by the good homogeneity in the drying : the standard deviation of the yield % was 0.7 %. The weight versus time curves were calculated from th experimental values by using a cubic-spline-interpolation method and the first derivative gave the drying rate curves. The drying rate (dm/dt depends on the air properties : the air velocity determines the mass transfer coefficient k, the air temperature and humidity fixes the parti water vapour pressure in air Pa and the saturated water vapour pressure at the product surface Ps'. The drying rate also depends on the ra of internal water migration which affects the surface water activity Aws :

$$dm/dt = k\,(Aws \,.\, Ps' - Pa)$$

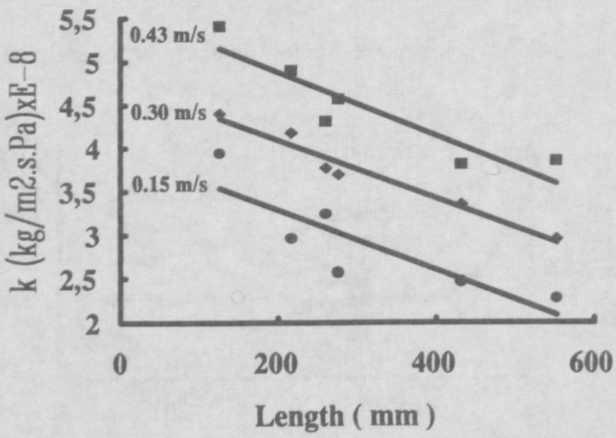

Figure 5 : variation of the mass transfer coefficient with air velocity and sausage length

The drying must be analysed in parallel with both the drying conditions and the water content profiles . In exp.B the drying rat fell down until the 8th day ; this is explained on the one hand by th reduction of Ps' when the air temperature decreased and on th other hand by the decrease in Aws due to the drop of the wate content at the surface. After the 8th day the drying rate wa approximately constant, between 10 and 15 g of water per day because the drying conditions and the surface water content wer almost constant. In exp.A, the evolution of the drying rate wa more complex but it can be interpreted using the previous metho The most interesting part which corresponded to the occurrence o a dry crust was delimited by the 8th and the 20th day . While th RH was low between the 8th and the 14th days the drying ra decreased dramatically to a value less than 5g/day. Conversel during the 6 following days the drying rate increased and reache approximately the same level as in exp.B. These variations seem be typical of the situation when the surface dries up, leading to a drop in Aws, and then rewetts. It is unfortunately impossible to measure directly Aws. However indirect measurements that would allow to evaluate Aws or a continuous analysis of the drying rate could be used to detect the formation of a dry crust and to modify automatically the drying conditions.

The analysis of the measured values of the mass transfer coefficient showed that the diameter does not affect this coefficient. Figure presents the results as a function of the sausage length and the air velocity. The straight lines related to the air velocities, calculated by line regression, are parallel : it is therefore easy to interpolate the value of k from figure 5 and to adapt the drying conditions from one sausag size to another by changing the air velocity.

CONCLUSION

The behaviour of both the drying kinetics and the water content profiles were analysed during the formation of a dry crust. Technic means that would allow to detect this formation and to modify the drying conditions are being investigated.

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