20TH EUROPEAN MEETING OF MEAT RESEARCH WORKERS

Session M.

Engineering Problems - the Cold Chain

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In this session the following three papers will be presented.

1. Bailey, C.: A Re-examination of the Factors Affecting the Chilling of Beef Carcasses

2. Fedorov, V G, L.D. Andreeva and D.N. Iljinskii.: The Investigation of Cooling and Shrinkage of Meat with the Help of Heat Flow-meters

3. Rogov, I.A., S.V. Nekroutman, E.G. Touryansky, V.A. Yasyreva.: Some Peculiarities of Heat- and Mass-transfer During Meat Thawing in the SHF-current Field.

Rapid chilling of meat carcasses after slaughter is beneficial from a hygienic point of view since growth and other activities of microorganisms are slowed down or halted. A rapid lowering of the temperature also minimizes the weight loss of the carcass caused by evaporation and consequently has economic advantages. It is therefore not surprising that the trend in meat industry for many years was to chill carcasses immediately after slaghter as rapid as possible in order to gain both these effects. In addition, a rapid cooling can increase the turn over. The meat can be sent for processing from the abattoir through the deboning and cutting plants quicker.

However, too rapid chilling may have some adverse effects on the quality of the meat, due to cold shortering. This sets in during the chilling if the temperature of the beef muscle falls below 11° C before the pH of the muscle has fallen below 6.2.

Cold-shortering also occurs in lamb and chicken muscle and probably also in pork muscle. The rapid post mortem decrease of pH in pork muscle, however usually prevents the development of cold-shortering. A pH value of 6.2 is reached before the temperature in the muscles is lowered to + 10° C also when operating a very effective chilling.

During the symposium "Meat Chilling, Why and How", in Bristol 1972, Dr Bendall of the Meat Research Institute stated:

"To allow a safety margin, and taking into account the fact that some carcasses will show high initial pH-values in the eye-muscle, it is recommended that lamb or beef carcasses should not be chilled below 10° C until at least 10 hours after slaughter". - - - - - -

This has gradually been accepted as a fact by most of the meat trade. In his paper C Bailey (1) points out that this does not mean that there is an agreement in how the chilling actually should be performed. On the contrary, many conflicting or even contradicting opinions are found in the literature. During the last years, however, much information and knowledge have been gathered about the factors influencing the rate of cooling of meat and the weight loss or shrinkage during this process. It is the use of well defined experimental conditions and reliable measuring methods which have made this possible. Much of the information has been gathered at the Meat Research Institute in Bristol, where there are excellent experimental facilities for this type of work. Chilling of whole sides of beef can be carried out experimentally with a wide variation of such parameters as air temperature, velocity and humidity. The experimental conditions are briefly described in the report.

Using this experimental carcass cooling tunnel and a mobile cooling unit, a research program was carried out in order ot investigate the effect of air temperature, velocity and relative humidity on the rate and evaporation from beef sides of different weight and fat cover. The program covered a large number of variables and the intention was to eventually provide the industry with necessary design information to enable chilling of beef under optimal conditions. Before we discuss the results hitherto obtained, I think it is worthwhile to briefly discuss the theory of shrinkage during cooling.

A carcass or cut of meat, which is surrounded by air cannot be chilled or frozen without a loss of water. This can be illustrated by using the relation between water vapour pressure and temperature which is given in figure 1. The figure refers to freezing but of course the same relations are valid during a cooling process.

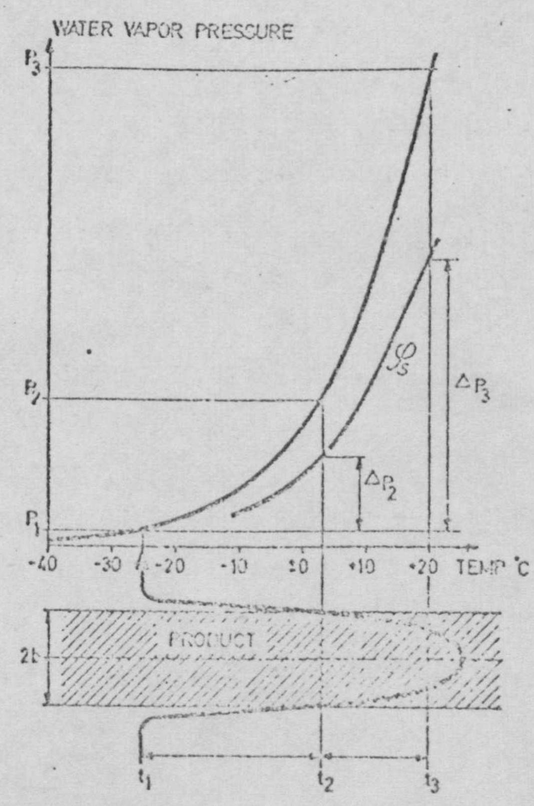

Fig. 1.

Below the curve for water vapur pressure is shown a cross section of a product with a solid line indicating the temperature gradient inside the product and in the air around the product. The air temperature is t_1, the product surface temperature is t_2. The temperature gradient inside the product influences dehydration only indirectly in that its average temperature, t_3, is a function of the total enthalpy of the product, which decides the time it will take to freeze (or cool) the product. If the product is homogenous, one finds the following relationship:

$$t_3 - t_2 = F\,(t_2 - t_1) \qquad (1)$$

$$t_3 - t_2 = \frac{F}{1 + F}\,(t_3 - t_1) \qquad (2)$$

$$F = \frac{h \times g}{k} \times \frac{1}{N} \qquad (3)$$

N = 3 (slab), 4 (cylinder) or 5 (sphere)

h = total heat transfer coefficient at surface of product

g = half of products thickness

K = thermal conductivity of product.

A wet product generates water vapour at a rate proportional to the difference between the vapour pressure at the surface of the product and that in the surrounding air $(P_2 - P_1)$. In meat, there is a resistance or barrier against diffusion of water vapour from the center of the product to the surface and from the surface to the air resulting in a reduction of the total vapour pressure at the surface of the meat. This can be expressed as the equilibrium relative humidity of the meat and the factor can be measured or calculated from results of cooling or freezing tests. The water vapour pressure difference causing dehydration will then be

$$\Delta P_2 = \varphi_s \times (P_2 - P_1) \qquad (4)$$

The basic law of water evaporation was presented by Bäckström (1926). His formula can be simplified if a certain approximation is allowed,

$$G = C \times M \times \frac{\Delta P_2}{t_2 - t_1} \qquad (5)$$

G = relative weight loss due to dehydration within given enthalpy limits
M = enthalpy differential of product
C = factor which is constant within $\pm$ 15 % for normal air and product (meat) temperatures.

According to this formula, the weight loss is lesser, the cooler the air is. ($t_2 - t_1$, is greater). The influence of the factor ΔP_2 was shown in the diagram. If the air and the product temperatures t_1 and t_3 are given, this factor is smaller the slower the temperature t_2 at the surface is. It is also evident that the heat transfer coefficient influences the weight loss quite substantially. This is illustrated by the relation between P_2 and P_3. The later represents a case of a poor heat transfer. The influence of the heat transfer efficiency is increasingly important the thinner the product becomes. It is natural that a thick product has less evaporation because it has a less surface exposed to the air, counted per unit of weight, the ratio surface/volume is smaller in a thick product than in a thin one. For meat carcasses this means that there are differences in evaporation losses from different parts of the carcass. In addition t_2 the temperature at the surface for the thinner parts will be closer to t_1 the air temperature (with a smaller difference $t_2 - t_1$) for most of the cooling time with the consequent reduction of ΔP_2.

Having this theoretical background in mind we can see the importance of optimizing the cooling process.

From the results obtained in the investigation by Bailey it is evident that the air temperature, when +4^o C and 0^o C are compared, has a significant influence on the time required to reach +10^o C in the centre of the meat.

It is perhaps more surprising to find that air velocities over 1 m/sec. have a very insignificant influence on the cooling time. But the results in fig. 1 and fig. 2 of the report clearly show the small extra timesaving obtained by higher air velocities. Neither does an air velocity over 1 m/sec. significantly reduce the evaporation losses. The author's conclusion from these observations is that there are little advantages in using values above 0.5 to 1 m/sec. since the small additional timesaving incurred would be unlikely to offset the considerable increase in capital and operational costs of the plant. This conclusion seems to me to be highly justifiable.

In fig. 4 of the report the influence of temperature on weight loss is also recorded. From a pure theoretical point of view one would have expected a lower evaporation loss when chilling was performed at an air temperature of 0° C than at one of + 4° C, provided that the conditions with regard to rel. humidity and air velocity were equal. The results obtained also show a lesser weight loss at 0° C but the difference is almost insignificant.

The fattiness and weight of carcasses have, as could be expected, a marked effect on both cooling time and evaporation losses. It is, as is pointed out, surprising how this has been overlooked in many investigations published about this subject.

The influence of weight and carcass fat will have some practical consequences since slaughtered animals in many abattoirs vary in size and fattiness but still must be cooled in the same cooling unit. Also the pronounced radiation losses, which have been clearly demonstrated in the experiments, will cause practical difficulties and should be taken into account when designing cooling equipment. Further research in this field is needed and it is therefore encouraging to learn that the work now presented is only an initial analysis and that further information is to be expected.

A different approach to optimize the cooling process of meat has been taken by Dr. V.G. Fedorov and co-workers at the Urkrainan Research Institu for Meat and Dairy Industry (2). Their work is presented in paper No. 2 i this symposium on page 210.

The authors have used small heat and mass flow-meters to measure the heat and mass transfer of different parts of the carcass in order ot find the influence of the various components of heat and mass balances - radiation convection and mass exchange of heat flow. Three different heat and flow meters were used, one for each of the above mentioned components. The one used for measuring the influence of mass transfer has tiny holes in the mass flow direction allowing moisture to pass through the instrument.

In this interesting report some experimental conditions are given as well as the theoretical calculations for the use of heat flow-meters. The authors also give a description of a combined heat and mass flow-meter used to easily find places on the meat surface with a uniform heat flow of all three components in the heat exchange.

When meat is cooled in air the rate of all three components of heat flow (radiation, convection and mass exchange) are of the same order. The components are recorded in an experiment (fig. 2 in the report) where a beef sample of 8 cm thickness is cooled in air. The air temperature during the first step of the operation (6 hours) was -14° C and was then changed to 0° C for the remaining 8 hours. During that time centre temperature was lowered from + 30° C to about + 4° C.

The rise in the air temperature gave a recorded marked decrease in the heat exchange and shrinkage.

No information of the surface temperature is given in the figure and I would like to ask the authors if the surface of the meat did not freeze during the first step of the operation.

The initial temperature of +30° C indicates that the experiment is performed on a carcass not long after the slaughter. One could therefore expect cold-shortening to take place in the meat. It should be interesting to know if this has been taken into consideration.

The technique used by the authors has also enabled them to determine and calculate the heat transfer coefficient from meat and to determine the coefficient for "dry" heat and the summary for the dry heat and heat loss from evaporation of moisture. Such recordings are given in figures 4 and 5.

The use of heat and mass flow-meters for studies of the heat and mass flow rates in chilling (and of course also heating) processes of meat is very interesting and I would like to ask the authors if they have compared the results obtained by this method with results from more conventional measuring techniques, such as the ones which were used in the previous report from MRI in Bristol.

The third and last paper in this symposium is presented by Dr. Rogov and co-workers from the All-Union Research Institute of Meat Industry USSR. It deals with meat thawing in SHF-current field (3).

Thawing of frozen foods including meat is unfortunately an operation much too neglected.

Very often thawing is performed under circumstances which cause deteriorati of the food due to growth of microorganisms or other quality changes. There are, however, today several methods for thawing meat as well as other foods. Such methods include thawing in air, steam and also so-called dielectric thawing. Thawing by use of air for heat transfer may be tailor-made for a special type of product or production line and gives a very good result without deterioration of the product. If temperature and rel. humidity is controlled the weight loss can be kept very low. Thawing under vacuum with steam also seems to give very good results. I therefore cannot share the opinion of the present authors who quite frankly state that by thawing in high temperatures "werden Nähr und Geschmackseigenschaften verloren" meaning that nutritional values and the taste of the product are destroyed by this thawing method. This is not true. I will show a picture (fig.4) of an arrangement for thawing whole pig carcasses or sides of beef. The necessary heat is pre-calculated and supplied by means of air. The temperature of the air is changed during the thawing cycle and the humidity regulated to give a finished product with a normal dry surface and an equalization temperature of the meat of +1 to 2o C.

However, also dielectric thawing has proven valuable under certain conditio Normally dielectric heating is carried out either at a low frequency, 10 - 100 MH_Z or at higher, 915 to about 2.500 MH_Z. Generally an increased frequency leads to a lower field strength for maintaining heating effect and to reduced power penetration. On the other hand, a lower frequency lead to bigger differences between materials of differing temperature of composition regarding heating effect.

In the present word the dielectric proporties of beef muscles of differing temperatures have been investigated. There is no doubt that dielectric thawing of meat for some purposes can be very useful and we therefore need as much information as possible about this technique. The present work provides us with some interesting data on the dielectric properites at various temperatures for meat.

One of the obstacles with dielectric thawing is that the absorption coefficient, ε'', increases with the temperature rise of the product. The increase of this factor varies for different products and also for different components in the product and since it is very high for water, the water content of a food has a great influence on the absorption coefficient and consequently on the rate of heating at different temperatures. Near zero, where ice starts to melt, ε'' normally increases very sharply. This may cause overheating in some parts of the thawed product while some parts are still not thawed. A phenomenon not unfamiliar in dielectric thawing.

The authors have determined the absorption coefficient in beef muscles using a frequency of 2 375 MH_z. The results encountered are in agreement with those found by other workers e g at the Swedish Institute for Food Preservation. In the present investigation ε'' at -10° C was 0.63. Bengtsson (SIK, Sweden) found this factor to be 1.3 at the same temperature using a frequency of 2.800 MH_z. At a temperature of +10° C he found ε'' to be 17, a more than 10-fold increase. I would like to ask the authors if they have any experience with temperatures above zero or if they in the melting zone of about zero degrees have found a sudden rise in ε''.

Temperature measurements in products heated in an electromagnetic field are difficult. In most cases the temperature is recorded by thermocouples inserted in the sample as soon as the power supply has been switched off. This procedure will, however, take some time and changes in temperature by conductivity may occur. It has been shown that the surface temperature falls very rapidly, 6 - 10° C in the first 10 seconds. This is probably a combination of radiation, heat loss due to moisture evaporation, and conduction. The change of temperature in the centre or under the surface is much lesser but some changes will occur before it is possible to record the temperature. If stationary thermocouples are used they must be screened, leading undoubted to interference with the elcetric field. It would therefore be of interest if the author would elaborate a little about this subject.

The penetration of microwaves of high frequencies is not very deep, 3 - 4 cms only, and this method therefore can only be used for thawing thin slices of meat or meat products like hamburgers with a suitable shape. Are there any experiments performed at your institute with lower frequences, where a deeper penetration could be expected? And a final question to the authors. Have you in any way compared the overall cost for thawing with microwaves compared with other thawing methods ?