Analysis of juice loss during the wet cooking of pork meat – Effect of temperature, muscle type and salt on water content

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ANALYSIS OF JUICE LOSS DURING WET COOKING OF PORK MEAT – EFFECT OF TEMPERATURE, MUSCLE TYPE AND SALT ON WATER CONTENT

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Abstract – Cooking loss (CL) and water content (X) during wet cooking were measured on 5 mm thick discs, 3x3x3 cm and 5x5x5 cm cubes of five muscles of pork: *semimembranosus* (SM), *biceps femoris* (BF), *rectus femoris* (RF), *semitendinosus* (ST) and *longissimus thoracis* (LT). During heating, water content in meat decreased to reach an equilibrium state (X_{eqCL}). Salt content, dimension and muscle type influenced X_{eqCL} but effect of temperature remained preponderant. Equilibrium water content differed when sample was vacuum-packed or not, but it was difficult to determine whether it was due to the effect of the surrounding juice or to the difference in pressure.

Key Words – cooking loss, heat transfer, water content.

I. INTRODUCTION

In industry, meat is often salted before being heated (cooked ham, roast, sausage, etc.). Salt reduction is very important for consumers because salt increases the risk of cardiovascular diseases and hypertension and because 20 % of salt consumption comes from processed meat [1]. Salt is mainly used to decrease water activity at meat surface but it also decreases cooking losses [2]. The control of cooking loss of salted product is of great importance for meat industry, because it determines the process yield and the microbial safety and shelf life of the product. It also affects sensorial (tenderness) and nutritional properties (micronutrients loss) of the meat.

Heating meat leads to protein denaturing and contracting and thus to juice expelling and cooking loss. In literature, many parameters are taken into account to explain cooking loss: meat temperature, animal species, muscle type, salt content, pH, etc. Oillic *et al.* [3] observed that when not-salted meat (beef, veal, horse, lamb) is cooked for a long time, an “equilibrium water content” is reached, X_{eq}, which depends on final meat temperature. X_{eq}, measured on meat cubes which side dimension ranged from 1 to 7 cm, was not affected by these dimensions. A model was developed to predict cooking losses on beef meat which should be applicable to lamb, veal and horse meat according to Oillic’s measurements [3].

The aim of the present work is to analyse cooking loss and water content on heated pork meat, salted or not-salted, and for different types of muscles. Studied factors are meat temperature, cooking time, dimension of meat piece and its initial salt content. The effect of the surrounding fluid (i.e. juice or water) and adverse pressure was also considered.

II. MATERIALS AND METHODS

Experiments were performed on four different muscles cut from pork ham: *semimembranosus* (SM), *biceps femoris* (BF), *rectus femoris* (RF) and *semitendinosus* (ST) and one dorsal muscle: *longissimus thoracis* (LT). Water content and pH of raw muscles are given in Table 1. Muscles were, vacuum-packed and frozen at -20 °C until the beginning of experiments.

Samples made of 5 mm thick discs, 3x3x3 cm and 5x5x5 cm cubes were cut in frozen meat, vacuum packed and then immersed in water-bath at 14 °C to be thawed. Accuracy on the cutting of the frozen muscle was ± 1 mm.

Table 1. Water content and pH in the raw pork muscles used for experiments. Water content is expressed as kg/kg of dry mass.

	SM	BF	RF	ST	LT
Water content	3.0±0.3	3.1±0.1	3.6±0.1	3.2±0.3	3.0±0.1
pH	5.7±0.2	5.8±0.1	6.1±0.3	6.3±0.2	5.4±0.1
Number of samples	111	6	18	18	6

Samples were, when necessary, salted by immersion in thin layer of brine for 50 hours, avoiding evaporation until the brine has been totally absorbed by the meat. Brine was made up with water and sodium chloride and salt content was chosen in order to reach 1.0, 1.5 or 2.0 % of salt in meat. In France, 2.0 % corresponds to the average salt content in the high quality cooked ham. Uniformity of salt content in meat discs was checked by sampling at several places in the disc (results not shown). Salt content was measured from chloride anion using ionic chromatography (Metrohm 850 professional IC).

To study the effect of the surrounding fluid and adverse pressure on cooking loss, samples were heated either directly by immersion in the water bath or by vacuum packing the sample prior to immersion. In this last case, it can be considered that meat surface is surrounded by expelled juice and that an adverse pressure is exerted at the surface of meat during heating. After heating, meat was cooled in iced water during 5 min. for discs and 15 min. for cubes.

Meat was weighed before heating (m_0), after cooking and after cooling (m_f). Cooking loss (CL) was calculated from (1):

$$CL = \frac{m_0 - m_f}{m_0} \qquad (1)$$

Water content in raw and cooked sample was determined by drying for 24 h about 3 g of meat in an oven at 104 °C and by weighting accurately the sample before and after the drying.

The experiment plan is presented in Table 2. Each cooking experiment was done in triplicate. Analyses of variance (ANOVA) were performed using R2.12.2.

Table 2. Experimental plan

Muscle type, Packaging & Salting conditions	**Temperature**	**Dimension and heating time**
SM unsalted and unpacked	50, 70, 90 °C	Disc 5 mm: 2, 5, 20 and 60 min. Cube 3 cm: 5, 15, 60, 120 min. Cube 5 cm: 15, 60, 120, 240 min.
SM unsalted and unpacked	Every 5 °C between 50 and 90 °C	Disc 5 mm: 60 min.
BF, RF, ST, LT unsalted and unpacked	50 and 70 °C	Cube 3 cm: 5, 15, 60, 120 min.
SM unsalted and vacuum-packed	50, 60, 70, 90 °C	Disc 5 mm: 60 min.
SM salted and vacuum-packed	50, 60, 70, 90 °C	Disc 5 mm: 2, 5, 20 and 60 min.

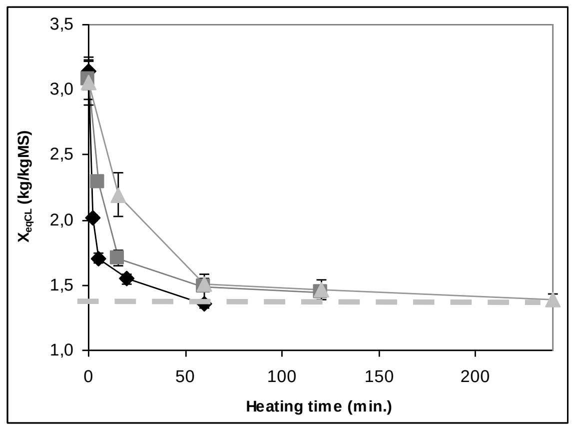

Figure 1. Time-variation of water content in *semimembranosus* samples of different sizes during a 90 °C heat treatment in a water bath. The value of the water content has been corrected to take into account the loss of dry matter in the juice. Symbols indicate the different sample dimensions: diamonds, squares and triangles correspond to 5 mm discs, 3x3x3 cm cubes and 5x5x5 cm cubes respectively

III. RESULTS AND DISCUSSION

Variation of water content with heating time

Figure 1 presents the time decrease of the water content in samples of different dimensions during a 90 °C heat treatment. The shape of the curve was the same for other water bath temperatures. Equilibrium water content was reached in the pork *semimembranosus* samples after a given heating time, as it was observed in literature for meat samples issued from beef, horse and lamb [3]. The slope of the curve was dependent on the sample dimension ($p = 0.00$) and water bath temperature ($p = 0.00$): water content decreased faster for higher temperatures and thinner samples (Fig. 1). It is often assumed in literature that dry mass is the same in raw and in cooked samples [4]. In this case, introducing water content of raw (X_0) and of cooked sample (X_f) in relation (1) leads to relation (2):

$$CL = \frac{X_0 - X_f}{1 + X_0} \qquad (2)$$

Applying relations (1) and (2) on our data led to differences in the resulting CL which could be as high as 15 % of the calculated value. This difference could only be explained by the loss of dry matter in the flowing juice which varied between 0 and 20 % of the juice's mass depending on cooking conditions. That means that water content expressed by X was overestimated compared to X_0.

Because the mass of water in X was divided by a smaller mass of dry matter than for X_0, the measured values of X were corrected in the following of this study by using CL determined from (1) to become X_{CL}:

$$X_{CL} = X_0 - CL \cdot (1 + X_0) \qquad (3)$$

Effect of sample dimension and temperature on equilibrium water content

Equilibrium water content (X_{eqCL}) is mainly affected by water bath temperature. On discs, it remains constant between 50 and 60 °C, decreases between 60 and 85 °C (Fig. 2). Then it significantly increases between 85 and 90 °C, this last variation has, to our knowledge, never been noticed in literature.

X_{eqCL} tended to decrease with sample dimensions (Fig. 2). This effect was significant from a statistical point of view sample ($p = 0.00$). However, variation was mainly observed between X_{eqCL} values measured on discs and those measured on cubes, while differences in X_{eqCL} values due to an increase in cube dimensions remained very small. That probably explains why the effect of sample dimension was not noticed on beef meat by Oillic *et al.* [3] with heated cubic samples only. Moreover differences which predominated at 50 °C tended to decrease with the increase of the water bath temperature (Fig. 2).

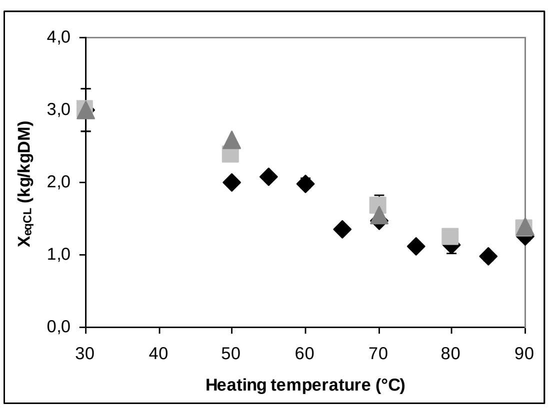

Figure 2. Corrected equilibrium water content in heated pieces of pork *semimembranosus* muscle X_{eqCL}, as a function of water bath temperature. Symbols indicate sample size: diamonds, squares and triangles correspond to 5 mm thick meat discs, and to 3x3x3 cm and 5x5x5 cm meat cubes respectively.

Influence of muscle type and vacuum packing

On unsalted 3x3x3 cm cubes, muscle type affected the equilibrium state ($p = 0.00$). At 50 °C, water content at equilibrium X_{eqCL} was correlated with water content in raw meat. For example, RF was moister than other muscles, raw (Table 1) as well as cooked at 50 °C (Fig. 3). When temperature increased, differences between muscles tended to reduce. Temperature effect was thus more important than muscle effect, confirming what was showed on beef muscles by Oillic *et al.* [3]. In the case of industrial cooking – temperature reach 70 °C for cooked ham and 90 °C for roast – effect of muscle type should be small.

Effect of vacuum-packaging was studied on 5 mm discs and revealed to be significant ($p = 0.00$). When meat discs were vacuum-packed, water content at equilibrium was always higher than when meat is cooked directly in water bath. Vacuum packing has two effects during cooking: (1) meat is surrounded by expelled juice which ionic strength is different from pure water, and (2) an adverse pressure is exerted at the surface of meat during heating. It is difficult to say which of these effects was predominant here.

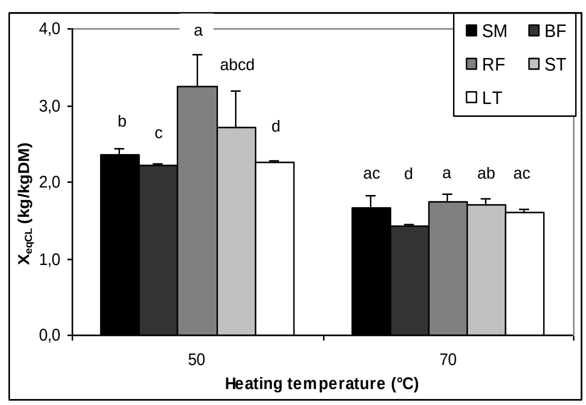

Figure 3. Effect of muscle type on the equilibrium water content corrected for loss of dry matter X_{eqCL} as a function of the water bath temperature for 3x3x3 cm cubes. Values not bearing common superscripts differ significantly ($p < 0.05$).

Influence of salt content on X_{eqCL} *for vacuum-packed meat discs*

Variation of the salt content of 5 mm vacuum-packed thick discs, affected the equilibrium water content ($p = 0.03$). At 60 and 70 °C, a variation of the salt content from 0 to 1.5 % seemed to have little effect on X_{eqCL} (Fig. 4) while a further variation up to 2.0% increased X_{eqCL}. At 90 °C, the effect of salt content on X_{eqCL} appeared always small; this was probably due to the preponderant effect of temperature. It seems from these results that a reduction of the salt content in cured ham muscles from 2.0 to 1.5 % will lead to an important decrease of cooking yield in industry (T = 70 °C). However this conclusion has to be checked using bigger sample dimensions.

IV. CONCLUSION

Kinetics of water content measured on not-salted pork meat cubes and discs, and on salted meat discs, have the same shape as those found in literature on meat issued from other animal species. Water content decreases to reach an equilibrium value which depends mainly on temperature. To be more accurate, water content value has to be corrected by taking into account the loss of dry matter in the juice. Equilibrium water content in discs tends to be lower than that measured on cubes while differences due to an increase in cube dimensions remain very small. Experiments on meat discs lead also to differences due to muscle type, vacuum packing or curing which are much lower than the variation due to temperature. Further research is needed to confirm these conclusions on meat cubes, to better understand the underlying mechanisms, and to model the variations of juice loss of pork meat cured or not-cured and heated under different conditions.

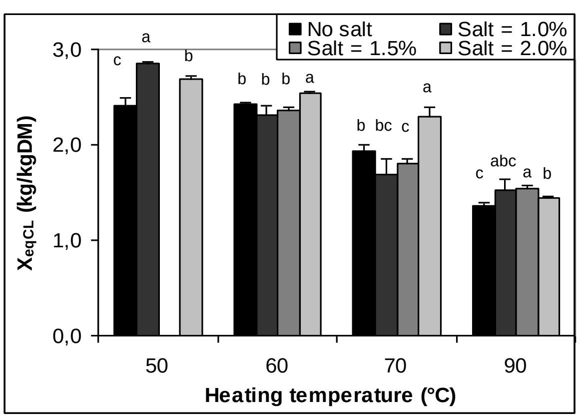

Figure 4. Corrected value of X_{eqCL} as a function of the salt content and of the heating temperature in 5 mm vacuum-packed discs of pork *semimembranosus* heated in water bath. Values not bearing common superscripts differ significantly ($p < 0.05$).

ACKNOWLEDGEMENTS

This work was funded by the Na-integrated program (ANR-09-ALIA-013-01) financed by the French National Research Agency.

REFERENCES

1. Desmond, E. (2006). Reducing salt: A challenge for the meat industry, Meat Science 74, 188-196.

2. Offer, G. and Knight, P. (1988). The structural basis of water-holding in meat. Part 1: General principles and water uptake in meat processing, in Developments in meat science - 4 (Lawrie, R., Ed.) pp 63-171, Elsevier Applied Science, London.

3. Oillic, S., Lemoine, E., Gros, J.-B., and Kondjoyan, A. (2011). Kinetic analysis of cooking losses from beef and other animal muscles heated in a water bath - Effect of sample dimensions and prior freezing and ageing, Meat Science 88, 338-346.

4. Laroche, M. (1978). Mise au point bibliographique. Facteurs influençant les pertes d'eau pendant la cuisson de la viande, Annales de Technologie agricole 27, 849-871.