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A POSSIBLE RELATION BETWEEN MUSCLE RESIDUAL GLYCOGEN AND YIELD OF MEAT PROCESSING BY CURING AND COOKING

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SUMMARY

The aim of this study was to investigate a possible influence of muscle residual glycogen on the yield of meat processing by curing and cooking. Twenty-eight rats were submitted to different treatments allowing to get very variable residual glycogen levels and ultimate pH in the post mortem muscle. From each carcass, the right leg was used for chemical measurements (pH, water, glucose, glycogen and protein) while the left leg was cured and cooked, the yields of the different steps of the processing being measured. The results showed that the residual glycogen level was related to the technological yield (weight after cooking/weight before curing) of the processing, independently of the ultimate pH.

INTRODUCTION

Meat from Hampshire pigs or Hampshire crosses has got in France the reputation of giving a low technological yield when processed into Paris ham (cured cooked ham). This defect firstly was attributed to the lower pH characterizing the meat from these pigs as compared to animals from other breeds (Monin and Sellier, 1985). However, reports from industrial research indicate that the inferiority in technological yield of the Hampshire meat is excessive in comparison with its inferiority in pH (Anonymous). An attractive hypothesis would be that the high water to protein ratio observed in the meat from Hampshire pigs could also contribute to the low technological yield, in addition to the effect of the low pH (Monin et al., 1986). This high water to protein ratio could be related to the very high glycolytic potential found in the white muscles of Hampshire pigs and Hampshire crosses (Sayre et al., 1963 ; Monin and Sellier, 1985 ; Essen-Gustavsson and Fjelkner-Modig, 1985 ; Mejenes-Quijano et al., 1986), since glycogen is able to bind 2 to 4 g of water per g (Greenleaf et al., 1969). Moreover, this water is likely to be "freed" during the post mortem glycogenolysis, becoming to some extent in excess relatively to the amount of protein. The present study was undertaken to investigate the possibility of a direct relation between the level of muscle glycogen and the technological yield of meat processing by curing and cooking. The rat was chosen as experimental model for evident reasons of cost.

MATERIAL AND METHODS

Twenty-eight rats were assigned to 4 groups of 7 animals each and submitted to the following treatments :

- the rats of the first group were rested and fed ad libitum a diet of commercial pellets and water till the time of killing. They were intraperitoneally injected with 150 mg/kg liweweight of Imalgene (a mixture of ketamine chlorhydrate and chlorbutol, Rhône Mérieux Laboratories). As soon as they were sleeping, they were injected again with 12 ml/kg liveweight of a solution of sodium iodoacetate at 0.33 g/ml. Death occured after around 10 min. This group was referred to as NI (N : Normal diet ; I : Iodoacetate).

- the rats of the second group were given the same treatment except that they were injected with sodium acetate instead of sodium iodoacetate, then killed by severing the spinal cord between the skull and the first vertebra, 10 min after acetate injection. This group was referred to as NA (N : Normal diet ; A : Acetate).

- the rats of the third group were obliged to swim till exhaustion, then fed a mixture of cooked rice and sucrose for 24 hours. They were then sacrificed in the same way as first group (Imalgene + iodoacetate). This group was referred to as SI (S : Sugar-rich diet ; I : Iodoacetate).

- the rats of the fourth group were treated in the same way as those of third group (sugar-rich diet) then killed in the same way as second group (Imalgene + acetate + severing the spinal cord). This group was referred to as SA (S : Sugar rich diet A : Acetate).

The treatments are summarized in table 1.

Table 1. Experimental treatments

Group	Preslaughter treatment	Way of killing
NI	Normal diet, rest	Imalgene + iodoacetate
NA	Normal diet, rest	Imalgene + acetate + severing of the spinal cord
SI	Exhausting exercise, sugar-rich diet	Imalgene + iodoacetate
SA	Exhausting exercise, sugar-rich diet	Imalgene + acetate + severing of the spinal cord

Two days after the sacrifice, the hind legs were skinned and separated from the body. Muscle tissue was carefully dissected from the right legs and minced in a small domestic mincer. Parts of the fresh mince were used for the determination of pH after homogenization in 10 volumes of water, and for the measurement of water content by drying in an oven at 104°C for 24 h.

The rest of the mince was freeze-dried and finely ground. 300 mg of powder were homogenized in 10 ml of cold 0.6 M perchloric acid, then glycogen (Dalrymple and Hamm, 1973) and glucose (Bergmeyer, 1974, using G-6-PDH and hexokinase) were determined. Parts of 50 mg of powder were used for triplicate determination of nitrogen according to Ferrari (1960), and the protein content was calculated as nitrogen x 6.25.

The left legs were carefully skinned and weighed (weight referred to as X_1), then put into a 15 % (w/w) NaCl solution maintained at + 4°C. After 2 days, the legs were taken out, carefully drained and weighed again (weight referred to as X_2). Then they were put into bottles containing 100 ml of the same NaCl solution ; the bottles were closed and put into a waterbath. At the beginning of the process, the waterbath temperature was around 8°C. The water was heated till a temperature of 70°C (this needed around 40 min), then the temperature was kept constant, the total time elapsed between the beginning of the heating and the end of cooking being 2.5 h. After this time, the bottles were immediately brought out of the waterbath and allowed to cool at ambient temperature, then the legs were taken out, carefully drained and weighed (weight referred to as X_3). The following yields were calculated :
curing yield = X_2/X_1 ; cooking yield = X_3/X_2 ; technological yield = X_3/X_1 = cooking yield x curing yield.
The data were computed using classical programmes for variance analysis, linear regression and principal component analysis.

Table 2. Results of the variance analysis

	Groups				F test		
	NA	NI	SA	SI	Diet	Killing	Interaction
Liveweight (g)	334	332	340	310	NS	NS	NS
Water (% of wet tissue)	74.6	74.9	74.7	74.7	NS	NS	NS
Protein (% of wet tissue)	22.3	21.8	21.8	22.0	NS	NS	NS
g of water/g of protein	3.34	3.44	3.42	3.39	NS	NS	NS
Glycogen (µmol/g wet tissue)	4.9	12.0	16.1	28.9	+++	++	NS
Glucose (µmol/g wet tissue)	5.6	8.7	8.3	8.7	NS	NS	NS
pH	6.17	7.18	6.09	7.17	+	+++	NS
Curing yield (%)	124	123	119	114	+++	+	NS
Cooking yield (%)	68	65	67	67	NS	NS	++
Technological yield (%)	85	81	79	77	+++	++	NS

F significance : NS Non significant + $P<0.05$ ++ $P<0.01$ +++ $P<0.001$

Table 3. Correlations between the traits under study.

	Water %	Protein %	Wat/prot	Glycogen	Glucose	pH	Curing y.	Cooking y.
Water %	1.00							
Protein %	- 0.64^{++}	1.00						
Water/protein	0.78^{++}	- 0.98^{++}	1.00					
Glycogen	- 0.27	0.02	- 0.09	1.00				
Glucose	- 0.21	- 0.10	0.04	0.30	1.00			
pH	0.15	- 0.16	0.16	0.36	0.33	1.00		
Curing yield	0.07	0.00	0.02	- 0.55^{++}	- 0.33	- 0.29	1.00	
Cooking yield	- 0.24	0.39^{+}	- 0.38^{+}	- 0.02	- 0.16	- 0.29	- 0.38^{+}	1,00
Technological yield	- 0.09	0.26	- 0.23	- 0.55^{++}	- 0.45^{+}	- 0.44^{++}	0.80^{++}	0.23

Significance : + $P<0.05$ ++ $P<0.01$

RESULTS

The results of the variance analysis are reported in table 2. The treatments efficiently influenced pH and residual glycogen. The pH was around 6.10 - 6.20 in the acetate-injected rats vs. 7.2 in the iodoacetate-injected rats. Among the former, the sugar-fed rats had a slightly lower pH than the normally fed ones. The treatments had any significant influence neither on the contents of water, protein or glucose, nor on the water to nitrogen ratio.

Both curing and technological yields were significantly affected by the treatments. An interaction between treatments was noted on the cooking yield.

The correlation coefficients between the traits under study are reported in table 3. The water to protein ratio was tightly related to the water content and above all to the protein content. The curing yield was negatively correlated with the glycogen content. The technological yield was negatively correlated with the glycogen and glucose contents, as well as with the pH ; it was positively related to the curing yield. The cooking yield was significantly correlated with the protein content, the water to nitrogen ratio and the curing yield.

Some relations between the traits under study are illustrated in figures 1 to 4. The results of the principal component analysis are reported in fig. 5. This figure visualizes i/ the opposition between the contents of glycogen and glucose on the one hand, and the curing and technological yields on the other hand ii/ the strong opposition between the protein content and the water to protein ratio iii/ the positive relation between the protein content and the cooking yield.

DISCUSSION AND CONCLUSION

The rat is not a very convenient experimental model for studies about the relations between the glycogen level and the technological quality, for various reasons :

- the level of muscle glycogen is low in the rested fed animal, as compared to the pig (20 to 50 µmol/g wet tissue in the rat -Mac Lane and Holloszy, 1979 ; Brooks et al., 1973 ; Sofrankova, 1975- vs. 35 to 140 µmol/g wet tissue in the pig -Sayre et al., 1963 ; Monin et al., unpublished data). In the present study, we tentatively calculated the glycogen level in the animal at the time of death, by summing glycogen, lactic acid, glucose-6-phosphate and glucose (the main glycolytic components in the post mortem muscle of meat animals) and we got levels of 38 µmol/g wet tissue in the normally fed animals vs. 55 in the sugar-fed. However these results were not computed together with the other data, because of their probable imprecision. The variations in residual glycogen also are low as compared to those observed in the pig muscle, since we got average values of 5 to 29 µmol/g wet tissue in rats, whereas Sayre et al. (1963) reported values of about 60 µmol/g wet tissue in Hampshire pigs vs. 1 to 5 in pigs from other breeds.
- the small size of the rat makes it very difficult to get very precise results about the technological process, in despite of the care taken for skinning and cutting the legs at a constant level. Small errors during cutting and draining processes can obviously lead to noticeable errors in the yields.
- the ultimate pH remains rather high (more than 6 on average in the muscles of the rat leg), even in presence of residual glycogen.

In the pig, it is admitted that the relations between

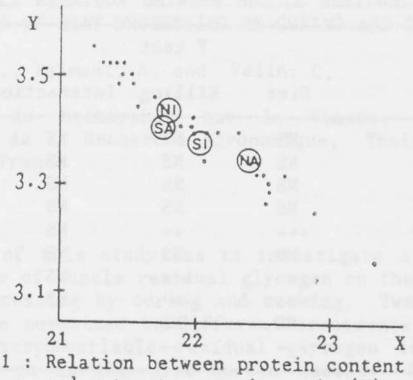

Figure 1 : Relation between protein content (X, in %) and water to protein ratio (Y).

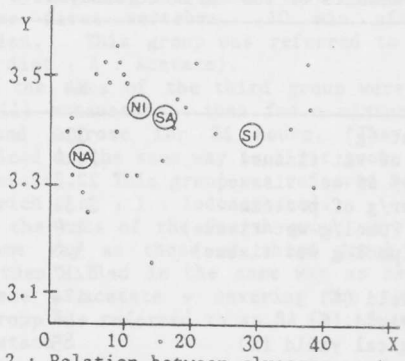

Figure 2 : Relation between glycogen content (X, in µmol/g wet tissue) and water to protein ratio (Y).

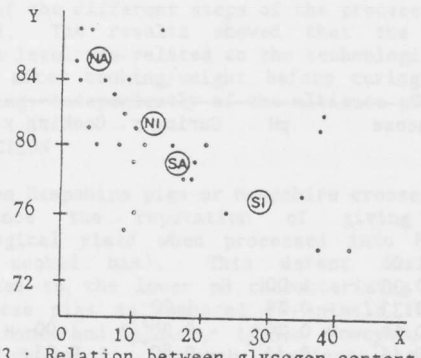

Figure 3 : Relation between glycogen content (X, in µmol/g wet tissue) and technological yield (Y, in %).

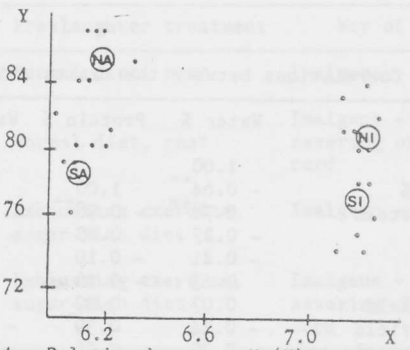

Figure 4 : Relation between pH (X) and technological yield (Y, in %).

• individual value

(XY) mean of the group XY

the ultimate pH and the different yields of the ham processing are positive (around 0.6 to 0.7 for the Paris ham -Jacquet and Ollivier, 1971 ; Jacquet et al., 1984). Here we found negative correlations. This can be interpreted as the fact that some other factors have more influence than the ultimate pH itself on the processing yields, in our experimental scheme. One of these factors seems to be the level of residual glycogen, which is related to both curing and technological yields to a similar extent, but not to the cooking yield. It is noteworthy that the difference in the technological yield between sugar-fed and normally fed rats reached 4 to 6 points within groups of similar ultimate pH, i.e. acetate-killed animals on one hand and iodoacetate-killed on the other hand.

Surprisingly, no significant difference was found in the water to protein ratio between the normally fed rats and the sugar-fed ones. This result does not support our hypothesis about a relation between the glycogen level and this ratio. However, it is somewhat hazardous to extrapolate from the rat to the pig. In fact, our hypothesis was made from a comparison between Hampshire and other pig breeds, which show differences in the glycogen content of white or intermediate muscles in the region of 40 to 80 µmol/g wet tissue (Sayre et al., 1963 ; Monin, unpublished results). The difference in muscle glycogen between the two groups of rats would be only around 15 to 20 µmol/g wet tissue according to the calculations reported above, and its consequences on the water to protein ratio are obviously more difficult to discern, taking into account the precision of the measurement techniques, particularly the method of protein determination.

In conclusion, our observations show that treatments inducing important variations in the residual glycogen content of the post mortem rat

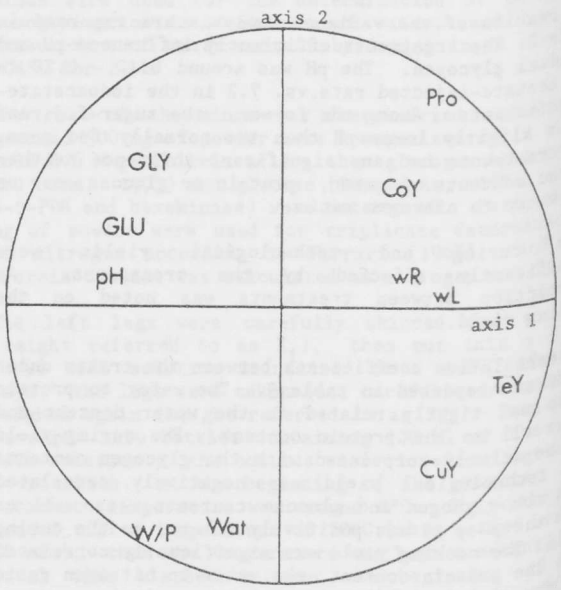

Figure 5 : Principal component analysis.

Wat : water content ; Pro : protein content
W/P : water to protein ratio ; GLY : glycogen content
GLU : glucose content ; pH : pH ; CuY : curing yield
CoY : cooking yield ; TeY : technological yield
wR : animal weight ; wL : leg weight

uscle are able to give also variations in the echnological yield of the processing (curing + ooking) independently of the ultimate pH. A lausible explanation consists in a direct effect of he glycogen on the binding of muscle water and in he release of glycogen-bound water during post ortem glycogenolysis and/or processing. It would be nteresting now to verify whether those results are ransposable to the pork processing.

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