Salt uptake and weight change after curing in normal and PSE porcine L. dorsi muscle

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PSE muscles are subject to high drip loss during storage (Wismer-Pedersen, 1959; Taylor & Dant, 1971; Warriss, 1982). Losses in weight greater than normal and a small increase in salt absorption were observed in cured PSE hams (Kemp et al., 1974; Kauffman et al., 1978) and in PSE meat processed to bacon (Taylor et al., 1973). Observations on weight changes and salt uptake in cured products vary according to the different processing methods, the joints and the characteristics choosen to select fresh meat. However, the final quality of cured meat seems slightly affected by the PSE condition, except for weight loss.
In Italy the PSE condition is frequently found in pigs slaughtered for curing hams and loins (Severini et al., 1984a; Severini et al., 1984b) and difficulties in processing PSE meat are sometimes claimed. In order to know whether this meat is unsuitable for the curing process and which technological changes can be eventually adopted to avoid defects, it is of utmost importance to investigate how weight change and salt absorption occur during the processing stages.
The present study was aimed at comparing the effect of curing on salt uptake and weight change in normal and PSE muscles. Model experiments were designed to control the curing as much as possible and to relate salt absorption and weight changes to the well defined characteristics of fresh muscles. For this reason slices of about the same size and weight were cut from Longissimus dorsi muscles and immersed in solution with different salt concentrations.

MATERIALS & METHODS

39 loins taken from crossbred pigs weighing 110-140 Kg were used for this experiment. The pigs were conventionally slaughtered at a commercial abattoir. Loins were divided in two groups according to appearance and pH at 1hr (pH-1) after death. 19 loins with pH-1 above 6.2 were classified normal and 20 loins with pale colour, watery structure and pH-1 below 5.8 were classified PSE.
At 45 min after death the appearance of the muscles were examined by three trained people.

The pH-1 was measured in three points of the Longissimus dorsi (LD) muscle transversely cut between the 5th-6th ribs by a pointed glass electrode using a Top Tronic pH-meter. The water holding capacity (WHC-1) was measured on samples taken from the LD muscle. The loins were collected in plastic containers at 10°C and transported to the Institute within one hour. The LD muscle was isolated and stored in a chilling room at 4°C. Samples were taken at 24, 48, 72hr after slaughter and analyzed for pH, WHC and moisture. Slices of about 50g, 1.5/2.0cm thick and with about the same surface area were cut across the long axis of the muscle immediately before storage and at various stages of the storage period.
Slices cut from the muscles at the beginning of storage were weighed and hung in a metal netting bag inside a plastic bag and stored at 4°C. The slices were weighed again after 24hr or 72hr to determine the weight loss expressed as percent of fresh meat weight.
Slices collected at 24hr after slaughter were weighed and immersed in 3%, 6% and 10% sodium chloride solutions, respectively, for 24, 48, 72hr. Each sample was hung in a beaker with 200ml brine and stored at 4°C and 12°C (3% and 10% solutions, only). After curing the slices were allowed to drain for 10 min, then weighed and analyzed for salt content and moisture.
Slices collected at 24, 48, 72hr after slaughter from the cooled muscle were weighed and immersed in 3% and 10% NaCl solutions, respectively, at 4°C as previously described. After 24hr the slices were allowed to drain for 10 min, then weighed and analyzed for salt content and moisture.
The pH at various storage periods was determined by a radiometer pH-meter using 10g of muscle homogenized in 50ml of 5mM neutral iodacetate solution.
Water holding capacity was measured according to the filter-paper absorption method on a sample of 0.3g and was expressed as value of meat film area/fluid area.
Sodium chloride content and moisture were determined by standard AOAC procedures (1980).

RESULTS

The characteristics of normal and PSE L. dorsi muscles at 1hr and 24hr after slaughter are shown in Table 1.

TABLE 1

Characteristics of muscles at 1hr and 24hr after slaughter

		NORMAL muscles	PSE muscles
pH-1		6.45(*)	5.51
WHC-1	≤ 1.0	-	12
	1.1-1.5	3(**)	5
	1.6-2.0	2	-
	> 2.0	14	3
pH-24		5.62	5.58
WHC-24	≤ 1.0	13	-
	> 1.0	6	20

(*) Mean value
(**) Number of pigs

All normal muscles had a pH-1 above 6.2 and a pH-24 below 6.0 (16 muscles had a pH-24 below 5.8) whereas all PSE muscles had a pH-1 below 5.8 and a pH-24 below 5.8.
Table 2 shows the amount of drip loss produced at 24hr and 72hr after slaughter (storage at 4°C). The drip loss in PSE samples is nearly double that of normal samples.
The mean values of NaCl content and weight gain in muscles after curing for different periods and at different temperatures are shown in Table 3. No significant difference between the mean values of salt content in normal and PSE muscles at any time and temperature of curing is observed. The salt absorption in both normal and PSE muscles is higher after curing in brines with a higher NaCl concentration and is slightly related to the length of the curing period. Indeed, the highest salt uptake is generally observed after 24hr and only a slight increase is detected after the following period in the samples cured in brines with 6% and 10% salt concentration. Neither normal nor PSE muscles show any significant difference between curing at 4°C and curing at 12°C, even though the mean values of samples immersed in 3% salt solution for 24hr and samples immersed in 10% salt solution for 72hr at 12°C are a little higher than those of samples cured at 4°C.
The mean values of weight gain in PSE muscles are generally higher than in normal muscles except after curing with 3% salt solution at 12°C. However, the differences are significant ($P < 0.05$) only between the samples cured in 6% and 10% salt concentration brines, although considerable variation is present within the groups, especially PSE. The weight gain in both normal and PSE samples increases with the curing period, at both 4°C and 12°C. The mean values of weight gain after curing at 4°C with 6% salt solution are higher than those of samples cured with 3% salt solution, but similar to those of samples cured with 10% salt solution. However, the values of weight gain in PSE muscles after 72hr of curing with 10% salt brine is greatly higher. Most mean values of weight gain after the different periods of curing at 12°C with 10% salt solution are higher than those of the same samples after curing with 3% salt solution. The values observed in normal and PSE samples at various times after curing with 3% salt solution at 4°C and 12°C, respectively, show no significant difference. Nor do the mean values of weight gain between PSE muscles after curing in 10% salt solution at 4°C and 12°C show a significant difference, but the values of normal muscles are slightly lower

TABLE 2

Average values of drip loss at different times after slaughter

muscles	drip loss(*) 24hr	72hr
NORMAL	1.51	2.55
PSE	2.70	4.39

(*) Expressed as percent of the initial weight.

TABLE 3

Mean NaCl content and weight gain values in normal and PSE muscles immersed in solutions with salt concentration for varying times and at varying temperatures.

length of curing period		3% salt solution number of samples	3% salt solution NaCl %	3% salt solution weight gain %	6% salt solution number of samples	6% salt solution NaCl %	6% salt solution weight gain %	10% salt solution number of samples	10% salt solution NaCl %	10% salt solution weight gain %
at 4°C										
24hr	Normal	8	1.54	9.6	7	3.23	11.4	4	6.17	11.5
	PSE	8	1.52	10.1	7	3.16	13.3	5	6.17	13.6
48hr	Normal	8	1.87	12.4	7	3.58	14.9	4	6.32	14.7
	PSE	8	1.91	13.6	7	3.60	16.9	5	6.48	17.3
72hr	Normal	8	1.85	14.1	7	3.74	17.6	4	6.46	18.0
	PSE	8	1.92	15.4	7	3.68	18.8	5	6.58	20.9
at 12°C										
24hr	Normal	6	1.65	9.9	-	-	-	4	6.08	9.5
	PSE	7	1.78	9.9	-	-	-	5	6.27	13.2
48hr	Normal	6	1.83	12.5	-	-	-	4	6.32	13.5
	PSE	7	1.85	12.9	-	-	-	5	6.50	19.0
72hr	Normal	6	2.01	14.2	-	-	-	4	6.65	15.7
	PSE	7	1.89	14.5	-	-	-	5	6.76	20.1

TABLE 4

Mean salt content and weight gain values of muscles cured for 24hr after different periods of storage at 4°C.

length of storage period		3% salt solution number of samples	3% salt solution NaCl %	3% salt solution weight gain %	10% salt solution number of samples	10% salt solution NaCl %	10% salt solution weight gain %
24hr	Normal	8	1.54	9.6	4	6.17	11.5
	PSE	8	1.52	10.1	5	6.17	13.6
48hr	Normal	8	1.63	8.3	4	6.43	10.7
	PSE	8	1.87	11.1	5	6.07	12.5
72hr	Normal	8	1.75	9.5	4	6.45	11.6
	PSE	8	1.82	11.9	5	6.06	11.6

after curing at 12°C than after curing at 4°C.
Normal muscles before curing had a mean value of 74.1% moisture and PSE muscles 72.8% moisture. The mean values of moisture after curing ranged from 75.3% to 77.8% with no significant difference between normal and PSE muscles, brines with different salt concentration, and the times and the temperatures of curing. The highest values were detected in samples cured for the longest periods.
Table 4 shows mean values of salt content and weight gain of samples cured for 24hr after the different periods of storage at 4°C. The normal and PSE muscles show no significant difference in salt uptake and weight gain. However, the value of salt content in PSE samples cured in 3% salt brine after a 24hr storage period significantly differs from those detected in samples cured after 48hr ($P < 0.01$) and 72hr ($P < 0.05$), respectively. The normal muscles show a slight average increase in salt uptake (non significant). By curing with 10% salt solution normal muscles showed a slight overall increase in salt content and PSE muscles showed two different tendencies. Two of them increased in the NaCl content and three showed a decrease. No correlation was found between this and the characteristics of the muscles at 1hr and 24hr after death nor with the pH and the WHC at the various storage periods.
The weight gain in both normal and PSE muscles cured with 3% or 10% salt solution is significantly constant, albeit the differing lengths of storage period before curing.
The mean value of moisture slightly decreased, but did not significantly change in normal and PSE muscles during the storage period at the cooling temperature. The values measured after curing ranged from 73.4% to 75.7% with no significant difference between the groups.

DISCUSSION & CONCLUSIONS

Longissimus dorsi muscles with pH-1 below 5.8 and PSE appearance showed a drip loss much higher than normal muscles with pH-1 above 6.2. This observation agrees with the results of Taylor and Dant (1971) and Warriss (1982) who found that LD muscles with pH-1 below 6.1 in storage showed a higher weight of drip than muscles with pH-1 above 6.1. Discrepancies between the values of drip loss could depend on the breed of pigs, the animals' age and the period and the temperature of storage. In this study a relatively wide range of WHC at 1hr after death was detected in muscles, especially in PSE muscles, in agreement with the results of a previous large scale survey (Severini et al., 1984a). It was shown that WHC values ranging from 1.5 to 2.0 were the most widely discriminating values between normal and PSE muscles. In the present study no significant correlation was found between pH-1, WHC-1 and drip loss within the group with pH-1 below 5.8 nor within the group with pH-1 above 6.2. The number of samples is too limited to enable any conclusion to be reached. However, it seems that in PSE muscles the different WHC-1 values have little or no effect on drip loss. This agrees with the observation (Warriss, 1982) that muscles with pH-1 below 6.1 show a rather constant weight of drip.
As regards the curing, normal and PSE muscles showed a similar salt uptake after immersion in 3%, 6% and 10% sodium chloride solutions at 4°C for up to 72hr. After the first 24hr of curing variation was observed within the groups, especially within PSE muscles. Extremely PSE meat tended to absorb a little more salt. However, no evident relationship between salt uptake and pH-1, pH-24, WHC-1 and WHC-24 was found within the groups.

Both normal and PSE muscles absorbed an amount of salt proportional to the NaCl content in brine. The salt uptake was generally higher during the first 24hr of curing period. The NaCl content at 24hr is higher than that observed by Wismer-Pedersen (1960) in similar conditions and this could depend on the different ratio meat weight/ml solution.
On the other hand, a difference in weight gain was observed between normal and PSE muscles after curing at 4°C, even though both muscles showed a very similar tendency. Indeed, PSE muscles showed a higher weight gain at the end of each curing time and with the various salt concentrations. This difference was more evident after curing with 6% and 10% salt solution. Variation existed within the groups, aboveall within PSE muscles after 24hr of curing, but no significant correlation was found between this and pH-1, pH-24, WHC-1 and WHC-24. This means that the weight gain was mainly related to muscle appearance and pH-1 below 5.8 or above 6.2. These results are concordant with the observation (Wismer-Pedersen, 1960) that whole muscles with a watery structure absorb more pickle than normal.
The highest weight gain in both muscles was reached by curing with 6% salt solution. Little or no improvement was observed by curing with 10% salt solution. Moreover, the gain in weight appears closely linked to the length of the curing period.
Increasing curing temperature to 12°C had little effect on salt absorption and weight gain in both normal and PSE muscles.
The weight gain during curing by immersion in brine is due to the absorption of salt solution, but is not closely relate to NaCl uptake.
Changes in the muscle cell membrane have been suggested to explain the high drip loss in PSE muscle (Wismer-Pedersen, 1960; Honikel and Kim, 1986). Increased membrane permeability could lead to higher brine absorption during curing and higher weight loss during drying. Wismer-Pedersen (1960) found that cured watery pork allowed to dry lost more drip than normal. Taylor et al.,(1973) showed that bacon from PSE pigs lost more weight than normal after maturation period. The final higher weight loss in PSE cured meat obviously leads to a higher salt concentration.
The results of the present study show that curing by immersion in salt solution causes a very similar salt uptake in normal and PSE muscles and a slightly higher weight gain in the latter. However, the wide range of values frequently observed within the groups suggests that appearance and pH at 1hr after slaughter are enough to discriminate muscles with different WHC, drip loss during storage and weight gain during curing, even though the brine absorption during processing appears to be affected by unknown factors.
In conclusion the curing of PSE muscles seems to lead only to a weight gain slightly higher than normal when this is expressed as percent of weight before curing. However, the weight gain is considerably lower than normal when it is expressed as percent of initial weight of the muscle a few hours after slaughter and before storage. This is because of the high drip loss during storage period. Moreover, the drip loss increases proportionally to the length of storage, but the curing leads to a similar weight gain after the different storage periods. Therefore, the curing of PSE muscles appears economically unfavourable and the long storage before curing increases the drip loss and negatively affects the final weight.
Further studies may shed light on how the drying period affects the salt content and weight of the cured PSE meat as compared to the normal meat.
The identification of meat not suitable for being cured and dried should be taken into account. Studies on this problem revealed the difficulty in correlating some characteristics of fresh muscle and in understanding how the quality of processed meat is related to these characteristics (Warriss and Akers, 1980; Barton-Gade, 1981; Severini et al., 1984a). At present, the PSE appearance and the detection of pH-1 below 5.8 seem reliable parameters for identifying the majority of meat which is potentially unsuitable for processing.

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