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Zusammenfassung

EINFLUSS DES GEFRIERZEITPUNKTES POST MORTEM UND DER LAGERDAUER VON GEFRORENEM M. LONG. DORSI VON SCHWEINEN AUF DIE DIFFUSION DER LAKE UND EINIGE EIGENSCHAFTEN DES MUSKELS

I. Untersuchung des Einflusses auf die Diffusion des Kochsalzes, den pH-Wert, Wasserbindungsvermögen und Plastizität

S. Rahelić, Ljiljana Jovanović und Vjera Pribiš

In dieser Mitteilung werden die Ergebnisse der Untersuchung des Einfrierens (bei -20°C) von m. long. dorsi von Schweinen zu verschiedenen Zeitpunkten p.m. (45 Min. und 24 Stunden), sowie der Lagerung des eingefrorenen Muskels (bei -20°C; 30, 90 und 180 Tage) auf die Kochsalzdiffusion, WBV, pH und Plastizität während der Naßpökelung (1, 3, 7, 10 und 15 Tage) dargelegt.

Mittels Varianzanalyse wurde jedoch festgestellt, dass der Gefrierzeitpunkt p.m., die Lagerdauer, die Pökeldauer, als auch Kombinationen dieser Faktoren signifikant die Kochsalzdiffusion in den Muskel beeinflussen. Desgleichen konnte festgestellt werden, dass der Gefrierzeitpunkt p.m. von signifikantem Einfluss auf den pH-Wert, das WBV in der Probenmitte und die Plastizität sind, während die Pökeldauer den pH-Wert, das WBV und die Plastizität, jedoch nur in der Probenmitte beeinflusst. Die Kombination von Gefrierzeitpunkt p.m. x Lagerdauer beeinflusst signifikant das WBV und die Plastizität der Proben, jedoch nicht auch den pH-Wert,

während andere Kombinationen dieser drei Faktoren wesentlich nur auf den pH-Wert der Probe während des Pökelns von Einfluss sind.

Durch statistischen Vergleich der Mittelwerte konnte indessen kein signifikanter Einfluss des Gefrierzeitpunktes p.m. und der Lagerdauer ($P < 0.05$) weder auf die Kochsalzdiffusion in den Muskel, noch auf den pH-Wert der gepökelten Proben.

Durch Vergleich der Untersuchungsergebnisse der Kochsalzdiffusion und der Veränderungen des pH-Wertes während des Pökelns von gefrorenen und nicht gefrorenen Muskeln konnten keine signifikanten Unterschiede ($P < 0.05$) festgestellt werden; dieser Befund steht nicht im Einklang mit den Befunden einiger Autoren, wonach die Lake schneller in gefrorenes Fleisch eindringt.

Summary

THE INFLUENCE OF FREEZING TIME POST MORTEM AND STORAGE TIME OF FROZEN PORCINE M. LONG. DORSI ON DIFFUSION OF BRINE AND THE CHARACTERISTICS OF THE MUSCLES

I Study of the Influence on NaCl Diffusion and pH, WHC and Plasticity

S. Rahelić, Ljiljana Jovanović and Vjera Pribić

In this paper the results of evaluation of the influence of freezing (-20°C) of porcine m. long. dorsi at varying p.m. time (45 minutes and 24 hours) and storage of frozen muscles (-20° C; 3, 30, 90 and 180 days) on NaCl diffusion, pH, WHC and plasticity during curing by submerging (1, 3, 7, 10 and 15 days) are presented.

By analysis of variance it is found that freezing time p.m., storage time, curing time as well as the combinations of these factors exert significant influence on NaCl diffusion in the musles.

Besides, it is found that freezing time p.m. influences significantly on pH, WHC in the middle of the sample and plasticity; storage time is found to affect both WHC of the surface layer and plasticity whereas curing time influences on pH, WHC and plasticity of the centre of the sample only. The combination freezing time p.m. x storage time significantly effects both WHC and plasticity of the samples, but not pH, whereas other combinations of these three factors influence significantly only pH of the sample during curing.

However, by statistical comparison of the mean values it is found that freezing time p.m. and storage time do not influence significantly ($P < 0.05$) on both NaCl diffusion in the muscles and pH of the cured samples (except for 7-day curing period).

Comparison of the results pertaining to evaluation of NaCl diffusion and pH changes during curing of both frozen and unfrozen muscles does not reveal any significant differences ($P < 0.05$) and this finding is not in agreement with the findings of some other authors who state that brine penetrates into frozen muscles at faster rate.

THE INFLUENCE OF FREEZING TIME POST MORTEM AND STORAGE TIME OF FROZEN PORCINE M. LONG. DORSI ON DIFFUSION OF BRINE AND SOME CHARACTERISTICS OF THE MUSCLES

I Study of the Influence on NaCl Diffusion and pH, WHC and Plasticity

S. Rahelić, Ljiljana Jovanović and Vjera Pribić

Meat freezing is a very suitable method of preserving so it is widely applied. Namely, considerable quantities of frozen pork are processed into various products, after thawing, during which it is also cured. As the opinion exists that both the freezing process and storage exert influence on muscle proteins it is logical to suppose that the changes in proteins, having occurred that way, will be reflected in the course of diffusion of brine as in the changes occuring in the muscles under the influence of the brine ingredients.

It is known that this problem has hardly been investigated so far and the purpose of our paper is to study the influence of freezing and storage time of frozen pork muscles on the course of NaCl diffusion as well as on some changes produced in the muscles by that brine component.

R e v i e w o f l i t e r a t u r e

Plank, according to Love (18) pointed to the possibility of protein damage in the muscles during water removal by freezing. Callow (4) states that muscle proteins denaturate during

freezing due to increase of the concentration of the salts in the unfrozen part of liquid. Luyet (19) suggests that some kind of the "mechanism of the injurious action" is activated during freezing and thawing of meat. Meryman points out, according to Lawrie (17), that proteins are altered under the influence of freezing temperature and storage time. Pavlovskij (21) points to the fact that freezing and thawing procedures of meat sligtly "deform" the protein molecules. However, longer storage of frozen meat produces more significant structural changes of proteins. These changes are greater if meat is frozen later p.m. and they occur predominantly in myosin. Sokolov et al. (25) have found that protein molecules of frozen meat aggregate during storage and form "supermolecular structures" resulting in poorer solubility. These changes are less evident if beef is exposed to freezing while hot, i.e. earlier p. m. Love (18) points out that freezing time p.m. rather than the temperature influences on the changes in meat. The same author (18) presents a number of the data on protein denaturation in dependence on storage time, but almost exclusively in fish muscles.

The literature is rather abundant with data on pH changes in the muscles at freezing and storage (13, 15, 23) as well as on proteolysis (14, 16, 18, 20).

In addition to the above references there is a number of the literature data on the changes in WHC of meat under the influence of freezing (2, 3, 5, 9, 13) as well as of the storage time (9, 13) that may be taken as an indirect finding on the changes in muscle proteins.

Pavlovskij (21) claims that meat frozen while hot, i.e.

frozen earlier p.m. has higher WHC and plasticity compared with the meat frozen later p.m. The same author has shown that both freezing and storage of frozen meat differently decrease WHC and plasticity of the muscles. If chilled meat is frozen more drip and proteins are separated at thawing. If hot meat is frozen WHC is better after thawing and it is more tender. However, Khan and van den Berg (14) think that freezing exerts slight influence on the quality of poultry meat. Gutschmidt (8) similarly presents for the meat of livestock whereas Šeffer and Cincadze (26) have found that the quality of rapidly frozen meat remains unchanged during the period od 6 to 10 month storage. Rahelić et al. (23) have also found that freezing of pork and beef muscles at -35°C and storage at -18°C do not considerably alter the characteristics of the muscles in the period up to 360 days. Goutefougea and Balin (6) have found that pork stored at -20°C (vacuum-packed) for the period of one year does not change, whereas slight changes occur for 2 years. Hofmann et al. (11) studied beef and pork stored at -20°C for 2 years and found that only slight chemical changes developed in the meat during that period which did not alter the quality of meat. Contrary, Sokolov et al. (25) have found that m. long. dorsi of the cattle frozen and stored at -12°C impairs its quality.

These statements should be supplemented with the data on the influence of curing time p.m. as well as freezing and storage of frozen meat on the course of that process. Regarding the freezing time p.m. Bate-Smith (3) cites the opinion of Callow that brine penetrates faster into the meat cured later p.m., i.e. when it transforms from the "closed" into "open" structure. Contrary, Mullins, according to Arganose and Henrickson (1) found that brine

diffused slightly faster into hot than chilled pork. Henrickson (10) also observed that brine penetrated significantly faster into hot than chilled pork ham. Rahelić et al. (23) did not find any significant differences in the rate of NaCl and $NaNO_2$ penetration into porcine muscles cured for varying time p.m. (45 min., 5 and 24 hours).

Data on the influence of freezing upon the course of curing are meager. Callow (4) states that freezing and thawing of the muscles increase "openness" of the microstructure of the tissue; thus, thawed muscle absorbs the salt solution faster than the muscle that has not been frozen. Speaking of the finding of Callow, Lawrie (17) cites the observation of the author that this acceleration amounts to 20%. Weir (27) also presents that thawed pork gets "more porous" so the penetration of the brine salts is faster compared with the unfrozen. Sokolov (24) presents a similar statement pointing out that the resistence coefficient to brine diffusion in thawed meat decreases, i.e. for meat frozen at $-10^{o}C$ by 40%, for meat frozen at $-17^{o}C$ by 30% and for meat frozen at $-24^{o}C$ by 10%. Wilson (28) emphasizes that frozen meat should be thawed prior to curing in order to permit brine diffusion and Sokolov (24) considers that "it is not recommended" to cure thawed pork that has been frozen longer than 3 months.

On the basis of the presented data we have decided to evaluate the influence of varying freezing time p.m. (45 minutes and 24 hours) and differing storage time of frozen pork (3, 30, 90 and 180 days) on the course of NaCl diffusion in the tahwed muscle cured by dipping. Besides, we have undertaken the study of the effect of these factors on pH, WHC and plasticity of cured meat.

Material and Methods

Material. For studies m. long. dorsi of the white lean marketing pigs, 6 to 8 months of age, weighing from 100 to 120 kg, was used. The muscle was separated from the carcass of a slaughtered animal in the region between the 4th and 12th thoracic vertebra.

The separated muscle was freed from fatty tissue and subsequently cut into seven, by length equal cuts, weighing from 150 to 250 g. These 7 cuts of the same muscle were used in all instances as a single sample being examined before freezing, after thawing, prior to curing as well as after 5 different time periods during curing. One group of the samples was frozen for 45 minutes p.m., the other for 24 hours p.m.

The samples were frozen at -20°C and wrapped in plastic bag, then stored in a cardboard box at the temperature of -20°C. Following 3 days and 1, 3 and 6 months, six samples were taken from each group. The samples were thawed at 4°C for 24 hours and subsequently dipped in the brine at the concentration of 12°Bé (1.385 kg NaCl, 7 g of sugar, 12 g $NaNO_3$ and 7 g $NaNO_2$ per 10 litres of water) in the ratio brine:meat 1:2. The cuts were cured in plastic boxes and during curing they were kept in the refrigerator at 4°C. The samples were analyzed after 1, 3, 7, 10 and 15 days of curing.

Method. The content of NaCl in the muscles was determined by means of "Salztester" Radiometer, type CDM 21a, directly in the sample. Before each measurement, the apparatus was calibrated in 5% NaCl solution. The content of NaCl was determined on the

surface (a), in the centre (c) and in the "middle" (b) of the sample. On the surface it was measured by inserting the electrode into the muscle at the depth of about 0,5 cm, in the centre it was measured in the halved sample in its geometrical centre and in the "middle" in the halved sample at the equal distance between the centre and surface of the sample.

pH was measured in the middle of the sample potentiometrically by means of the contact portable pH-meter, Radiometer, type PHM 24.

WHC and Plasticity were determined by Höppler consistometer (12), after the modified method of Grau and Hamm (7) for determination of WHC by compression. The studied sample was compressed by loading of 20 kg/1 minute. These characteristics were measured on the surface layer (a) and in the central part (b) of the sample.

Statistical analyses were performed on the basis of three factorial analysis with 6 repetitions and distribution of the units according to the randomized block system.

By such design of the test upon analysis of variance and F-test evaluation of the influence of the studied factors on the whole and their interaction is feasible. Estimation of the significance of individual comparisons of the variants within each factor as well as their interaction were performed on the basis of lsd-test. Estimate of the significance of the differences in both tests was conducted at the level of significance of 5%.

Results and Discussion

Diffusion of NaCl. The results of studying NaCl diffusion into thawed muscle samples frozen for 45 minutes and 24 hours p.m. are presented in figure 1a and b and table 1. In both figures the course of NaCl diffusion into infrozen samples was parallelly demonstrated.

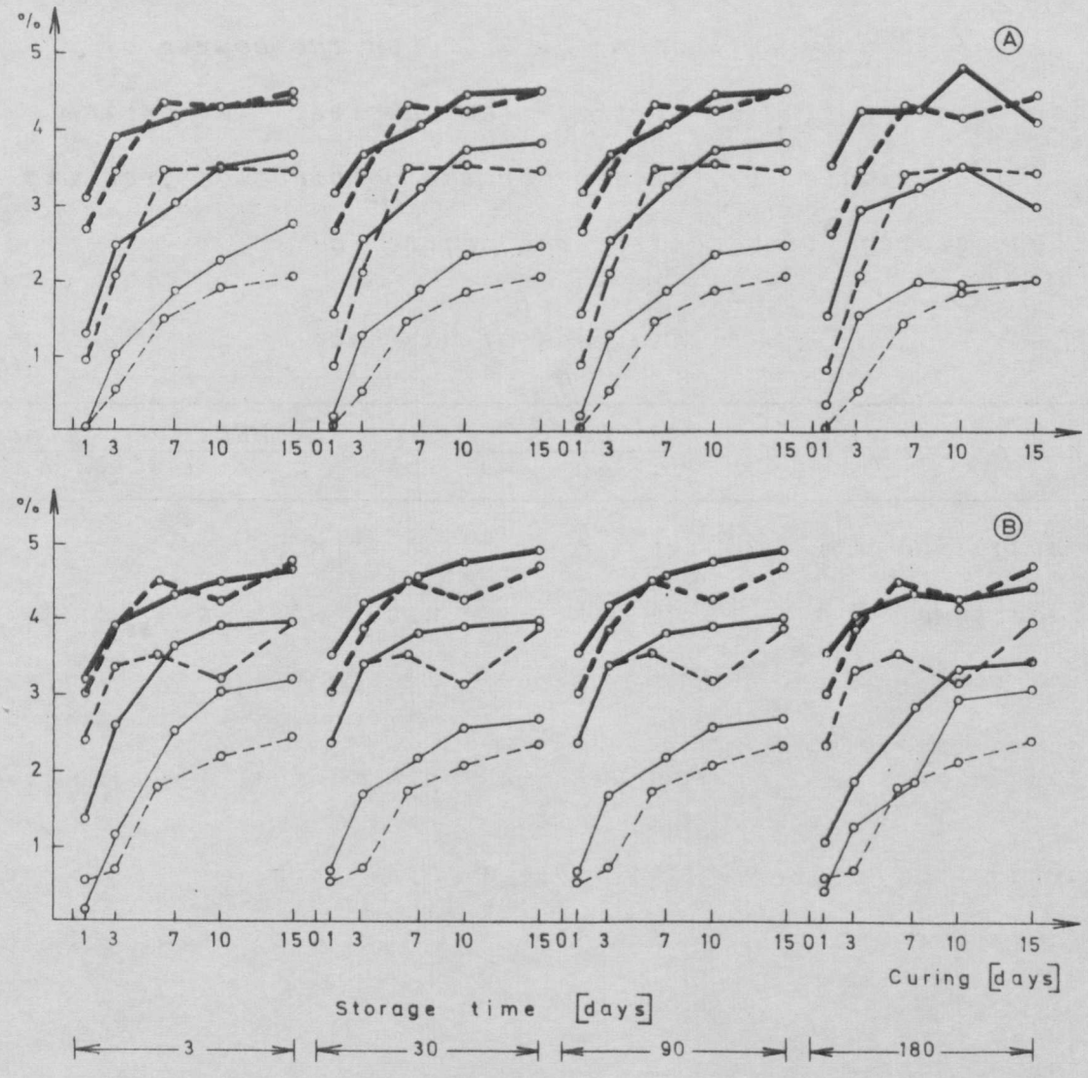

Fig. 1. DIFFUSION OF NaCl IN SAMPLES OF M. LONG. DORSI OF PIGS FROZEN 45 MIN (A) AND 24 HOURS (B) P.M., STORED FOR DIFFERENT TIME AND CURED BY DIPPING AFTER THAWING AS WELL AS UNFROZEN SAMPLES CURED BY THE SAME PROCEDURE

Thawed: —— Surface layer (a), —— Medium layer (b) i —— Center (c)

Unfrozen: – – Surface layer (a), – – – Medium layer (b) i – – – Center (c)

From the results obtained it is seen that NaCl diffuses into the muscles faster on the first days of curing but diffusion proceeds to the 15th day. NaCl concentration reaches the value of 2 to 3% in the centre of the sample by the end of curing.

By analysis of variance (table 1) it has been found that freezing time of meat p.m., storage time of frozen meat as well as curing time and the combinations of the above three factors significantly influence ($P < 0.05$) on the course of NaCl penetration into all studied parts of the samples, i.e. on the surface (a), in the middle (b), except for the combination freezing time p.m. and storage time, and in the centre (c).

Analysis of variance

Table 1

Source of variantion	NaCl			pH	WHC		Plasticity	
	a	b	c		a	b	a	b
Freezing time p.m.	*	*	*	*	n.s.	*	*	*
Storage time	*	*	*	n.s.	*	n.s.	*	*
Curing time	*	*	*	*	*	*	n.s.	*
Freezing time p.m. x storage time	*	*	*	n.s.	*	*	*	*
Freezing time p.m. x curing time	*	n.s.	*	*	n.s.	*	n.s.	n.s.
Storage time x curing time	*	*	*	*	n.s.	n.s.	n.s.	n.s.
Freezing time p.m. x storage time x curing time	*	*	*	*	n.s.	n.s.	n.s.	n.s.

a - surface layer of the sample; b - middle layer of the sample; c - centre; * - Significant $P < 0.05$; n.s. nonsignificant.

Since in the previous paper (22) we have studied the course of NaCl diffusion and pH of unfrozen muscles cured under the same conditions, we are able to use those results now.

In order to evaluate the influence of freezing and storage on the course of NaCl diffusion into the muscles, the course of NaCl penetration at curing of unfrozen muscles is demonstrated in the same figure (fig. 1a and b). By comparison of these findings it is seen that NaCl diffuses at equally the same rate into the surface and middle layer of both unfrozen and frozen samples. By statistical comparison of the mean values the differences are found to be insignificant ($P < 0.05$). However, NaCl penetrates into the central part of the frozen samples at slightly faster rate but these differences are found to be insignificant ($P < 0.05$) in all curing time periods.

On the basis of the results obtained no differences in the rate of NaCl penetration at curing of frozen and unfrozen muscles are expressed. Thus, these results are not in agreement with the findings of Callow (4), Weir (27) and Sokolov (25) who claim that brine salts penetrate at faster rate into the frozen than unfrozen samples.

<u>pH.</u> Figure 2a and b and table 1 demonstrates the results of pH of the samples frozen for 45 minutes and 24 hours p.m. and stored, subsequently cured following thawing. From the results it is seen that pH of the samples frozen for 45 minutes p.m. decreases considerably after thawing while it slightly changes during curing. pH of the samples frozen for 24 hours p.m. slightly alters after thawing whereas it varies less during curing.

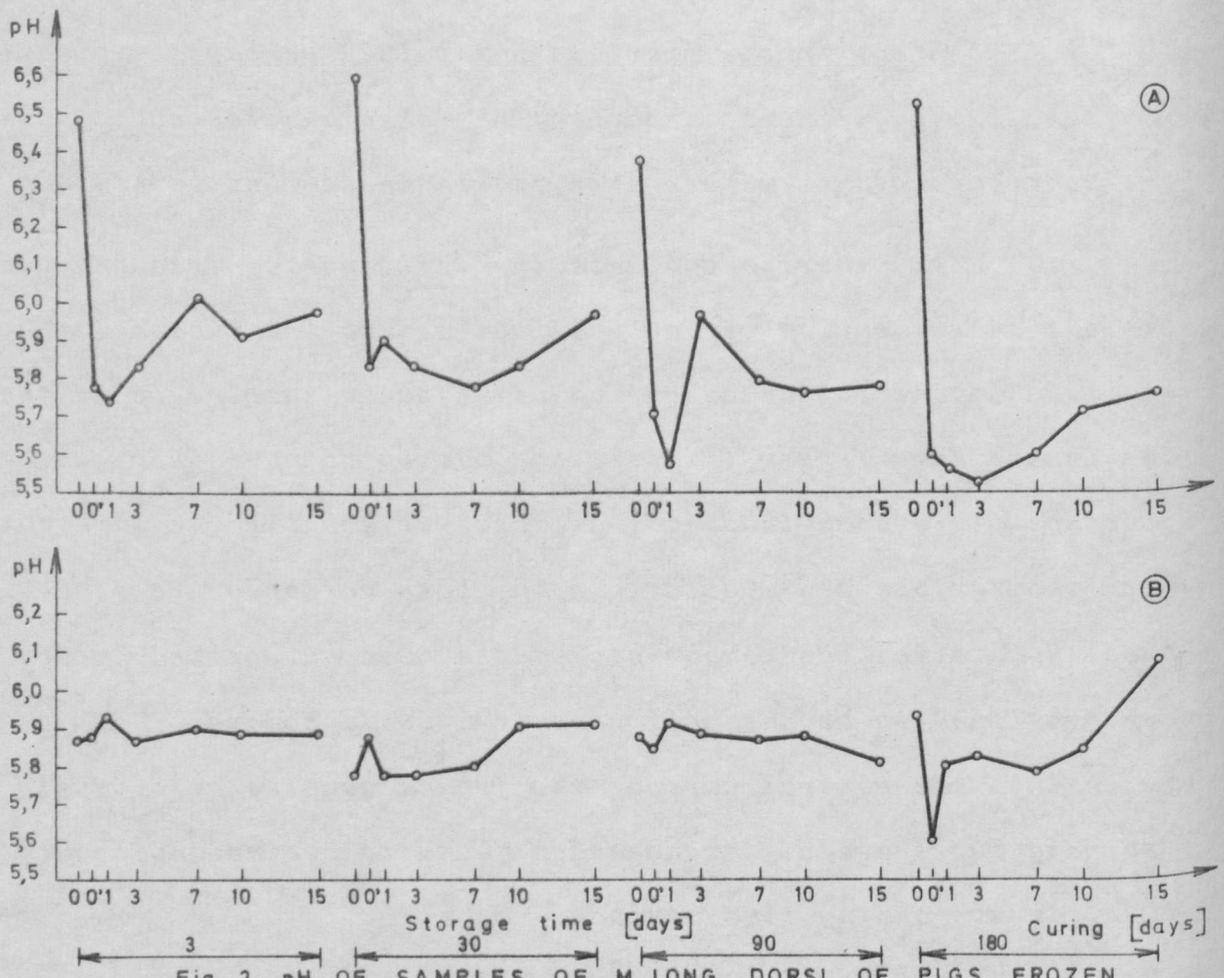

Fig. 2. pH OF SAMPLES OF M. LONG. DORSI OF PIGS FROZEN 45 MIN (A) AND 24 HOURS (B) P.M., STORED FOR DIFFERENT TIME AND CURED BY DIPPING

By analysis of variance (table 1) it has been found that only freezing time p.m., curing time and the combination of these factors significantly influence on pH of the muscles at curing.

By statistical comparison of the mean values of pH of the frozen and unfrozen samples during curing, significant difference is found only for 7-day period of curing. During that curing time the amount of the salt reaches the value of about 4%. For the other curing time periods the differences in pH of this group of muscles are not significant.

WHC. From the results in figure 3a and b WHC of the surface layer is found to increase only on the first day of curing

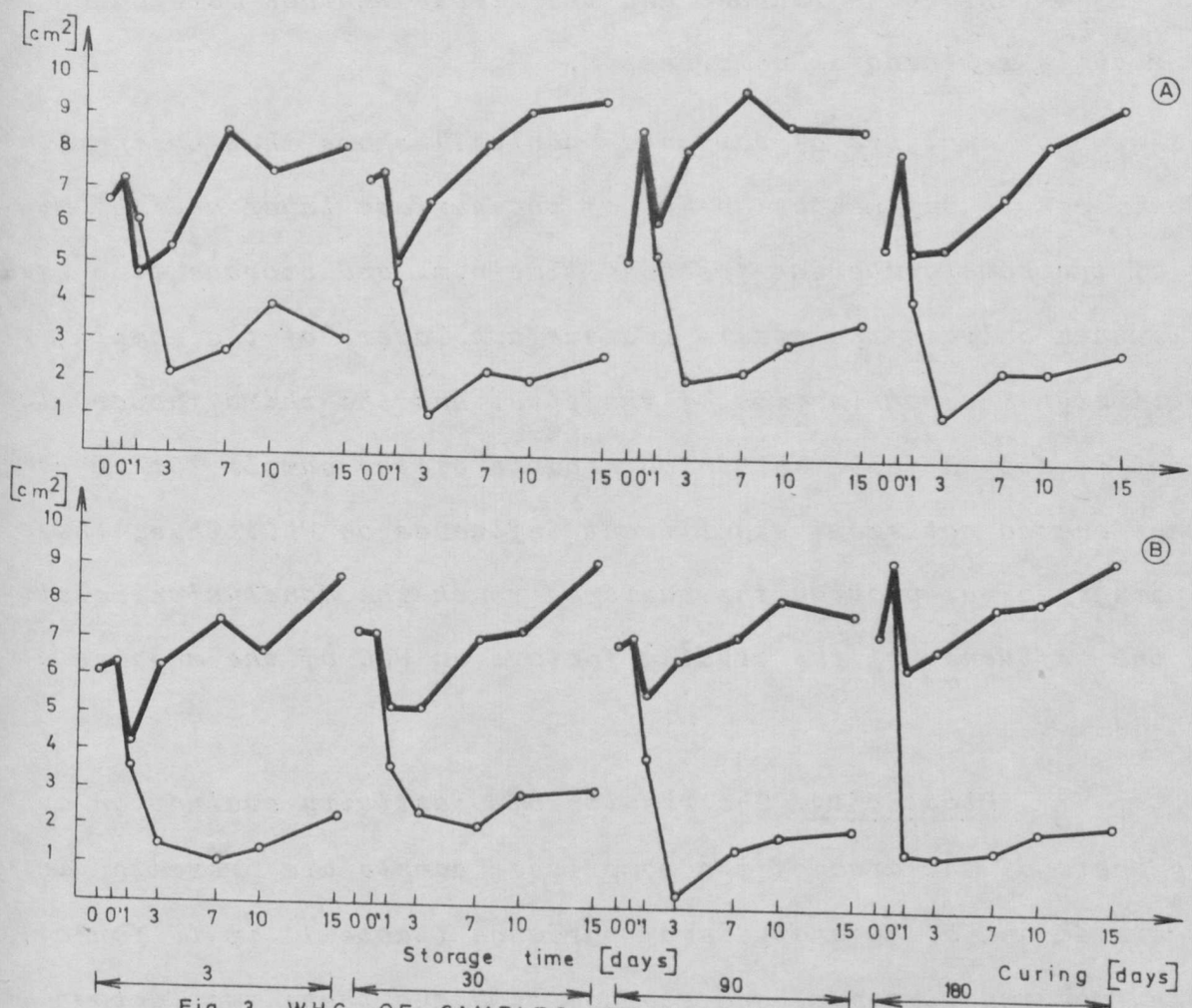

Fig. 3. WHC OF SAMPLES OF M. LONG. DORSI OF PIGS FROZEN 45 MIN (A) AND 24 HOURS (B) P.M., STORED FOR DIFFERENT TIME AND CURED BY DIPPING

——— Surface layer (a), —— Center (b)

and afterwards it decreases quickly to the termination of curing. Contrary, in the middle of the samples WHC increases distinctly until the third day of curing and thereafter slowly decreases. It is probably due to NaCl concentration which in the surface layer reaches the value of about 3% on the first day and 4% on the third

day. On the other hand, NaCl concentration in the middle of the sample reaches the value of about 3% as late as 15th day of curing. Besides, more proteins are washed out from the surface layer at curing by which WHC is reduced and the tissue imbibes more water that is readily released at compression.

Analysis of variance (table 1) shows that curing time significantly influences on WHC of the surface layer and the middle of the sample whereas freezing time p.m. and storage time exert influence only on the middle and surface layers of the sample, respectively. The combination of the first and the third factor also significantly affects WHC in both parts of the sample. Other combinations do not exert significant influence on WHC. Thus, these findings do not provide the basis to reach the conclusion relative to the influence of the studied factors on WHC of the muscles at curing.

Plasticity. The results of plasticity evaluation on the basis of the area of the compressed sample are presented in figure 4a and b. By analysis of variance (table 1) it is found that both freezing time p.m. and storage time and these two factors together significantly influence on plasticity of of the muscles at curing. Curing time exerts influence on plasticity only in the centre of the samples. Other combinations of the factors do not significantly influence upon this characteristic of the muscle.

Conclusion

The results of these studies indicate that freezing time, storage time and curing time as well as the interaction of these factors significantly influence on NaCl diffusion in all

layers of frozen samples. However, these factors do not exert influence, expressed in the same extent, upon pH, WHC and plasticity.

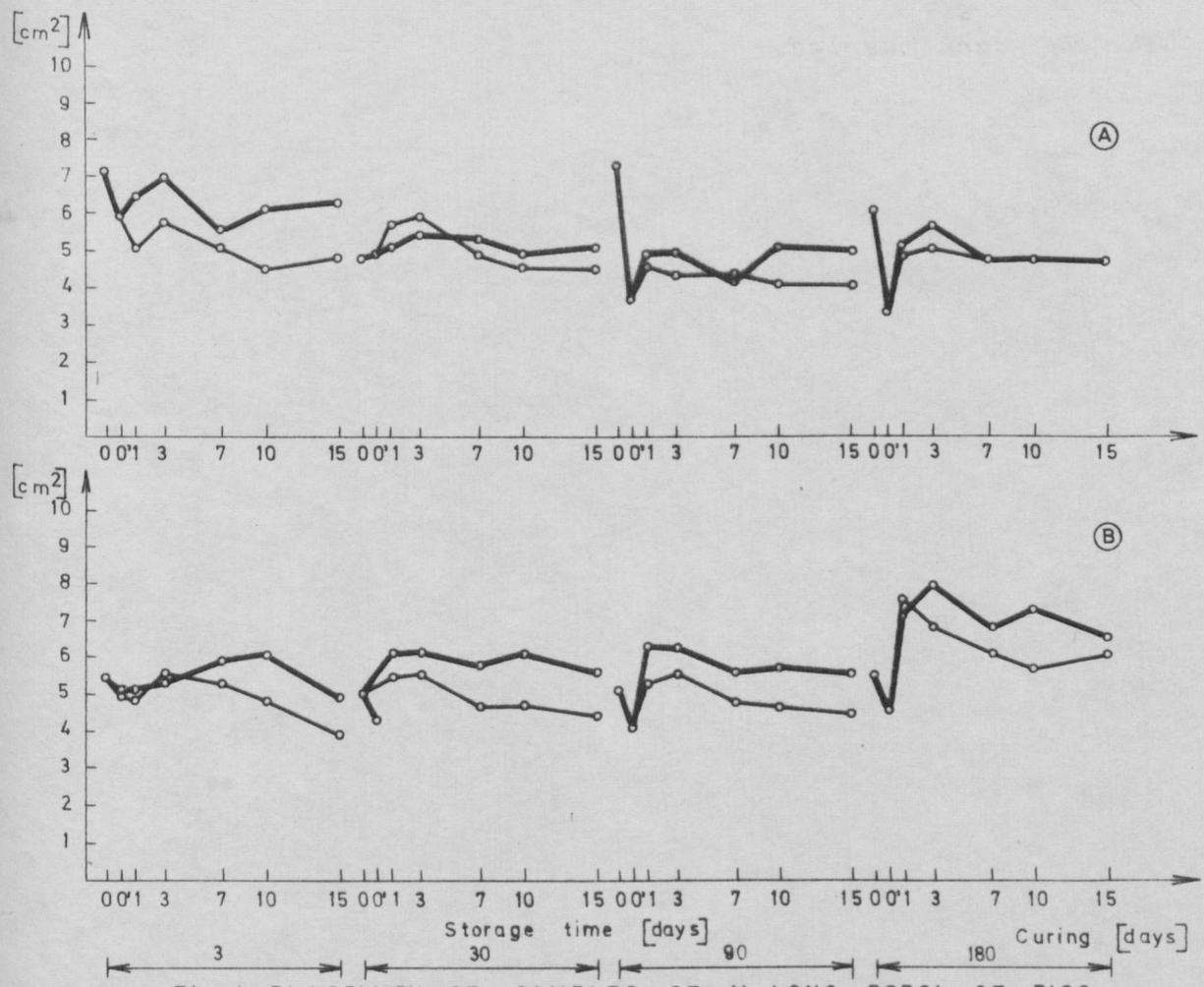

Fig. 4. PLASTICITY OF SAMPLES OF M. LONG. DORSI OF PIGS FROZEN 45 MIN (A) AND 24 HOURS (B) P. M., STORED FOR DIFFERENT TIME AND CURED BY DIPPING
Surface layer (a) ——, Center (b) ——

However, the number of the studied samples is not sufficient to permit to draw the reliable conclusion on the influence of the studied factors upon these characteristics of cured meat on the basis of the results obtained under these conditions.

It is worth mentioning that by comparison of the

results of curing of both frozen and unfrozen muscles no significant differences are found during NaCl diffusion as well as in pH of the muscles. This finding is not in agreement with the findings of Callow (4), Weir (27) and Sokolov (25) who have found that brine penetrates into frozen muscles at faster rate in comparison with unfrozen muscles.

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