Phospholipid changes during cooling of pork treated by different mechanical and heat procedures

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M. longissimus dorsi of pigs was used for the examination. The results obtained by the examination of raw, pasteurized and sterilized samples of meat pieces and homogenates as well as roasted meat slices, during their storage at 2 to 3°C, point at permanent decrease of phospholipid content. The increase of free fatty acid content was registered in all experimental samples. Changes in free fatty acid content were in all cases more pronounced in homogenates than in meat pieces, being more obvious in raw than in heat treated samples.

Oxidative changes of lipids were expressed to the lowest extent during storage of raw meat pieces. On the contraty, in pasteurized and raw homogenates these changes were pronounced whereas in sterilized homogenate and roasted meat they were expressed to somewhat lower extent.

On the basis of the established contribution of phospholipids to oxidation and hydrolysis of total lipids, it has been established that oxidative changes during storage of samples are first of all the consequence of phospholipid oxidation.

Veränderungen an den Phospholipiden im Laufe der Kühlung von mechanisch und thermisch behandeltem Schweinfleisch

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Bei der vorliegenden Untersuchung hat man sich des M.longissimus dorsi bedient. Die Untersuchungsergebnisse, die im Laufe der Lagerung von den rohen, pasteurisierten und sterilisierten Fleischsücken und Homogenaten, als auch von dem gebratenen und danach aufgeschnittenen Fleisch bei einer Temperatur von 2 bis 3°C erzielt wurden deuten auf die permanente Herabsetzung des Phospholipidengehaltes hin. Bei all diesen Versuchsproben wird eine Steigerung am Gehalt der freien Fettsäuren registriert. Die Veränderungen in dem Gehalt der freien Fettsäuren ist in allen Fällen bei den Homogenaten ausgeprägter als bei den Fleischstücken und stärker augenscheinlich bei den rohen als bei den thermisch behandelten Proben.

Oxydative Veränderungen an Lipiden sind am geringsten im Laufe der Lagerung von rohen Fleischstücken. Demgegenüber sind diese Veränderungen ausgeprägter in den pasteurisierten und rohen Homogenaten und in etwas kleinerem Masse bedeutend in dem sterilisierten Homogenat, als auch in dem gebratenen Fleisch.

Es wird aufgrund des ermittelten Phospholipidenanteiles in der Oxydation und Hydrolyse der gesamten Lipiden, festgestellt dass die oxydative Veränderungen im Laufe der Probelagerung vor allem die Folge der Phospholipidenoxydation ist.

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Changements de la teneur en phospholipids dans la viande des porcs traite par divers traitements mécaniques et termiques pendent refroidissement

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Pour l'examination on a utilisée M. longissimus dorsi des porcs. Les résultates des investigations pendent refroidissement á 2-3°C les pieces et les homogénés de la viande fraiche, pasteurisée et stérilisée, et de la viande rôti ont indiquée que le décroissement de la teneur en phospholipides est permanent. Dans tous les ocasions on a constaté l'accroissement de la teneur en acides gras libres. Changements de la teneur en acides gras libres dans tout les occasions sont plus expressiffes dans les homogénés que dans les pieces de la viande, plus aprecevable dan les échantillons fraiche que dans les échantillons traité termiques.

Les modifications oxydatives des lipides sont les moins an cours de la conservation des pieces de la viande fraiche. Au contraire, cettes modificcations sont plus marquée dans les homogénés fraiche et pasteurisée et un peu moins marquées dans les homogénés stérilisée et dans la viande rôti.

Sur la base de contribution constaté des phospholipids dans les modifications hydrolitiques et oxydatives des lipides, on peu constaté que les changements oxydatives pendent conservation des échantillons ont apres tout conséquence de l'oxydations des phospholipids.

Фосфолипидные изменения в течение охлаждения свинины обработанной различными механическими и термическими способами

ВЕСЕЛИНКА ДЖОРДЖЕВИЧ, РАДОЛЮБ ТАДИЧ, ФРАНЦ БУЧАР и ИВАНА ДЖУИЧ

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Для исследования использован M.longissimus dorsi . Результаты исследования сырых, пастеризированных и стерилизированных образцов взятых из кусков мяса и гомогенатов, а также и из нарезков жаренного мяса во время хранения на складе при 2 до 3°Ц показывают перманентное понижение содержания фосфолипидов . у всех экспериментальных образцов регистрировано повышение содержания свободных жирных кислот. Изменения в содержании свободных жирных кислот являются во всех случаях более выразительными у гомогенатов чем у кусков мяса и более наглядными у сырых чем у термически обработанных образцов.

Оксидативные изменения липидов наименьшие в течение складирования сырых кусков мяса. По противоположно этому данные изменения резко выражены у пастеризированных и сырых гомогенатов, пока они в меньшей степени значительны в стерилизированном гомогенате.

На основании утвержденного причастия фосфолипидов в оксидации и гидролизе совокупных липидов констатируется что оксидативные изменения в течеченье складирования образцов являются , прежде всего, последствием оксидации фосфолипидов.

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Phospholipid changes during cooling of pork treated by different mechanical and heat procedures

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Introduction

Changes of phospholipid content during meat storage are known to a very small extent (1,3,4, 7,8). In the available literature we did not find data on the changes of phospholipids and neutral lipids during storage of meat treated by different mechanical and heat procedures. For that reason, the aim of this work was to examine changes of phospholipids and total lipids during cooling (at 2-3°C) of meat treated by different mechanical and heat treatments being of importance for industrial practice and culinary art.

Material and Methods

For these examinations, M.longissimus dorsi of domestic white meaty pigs, about 6 months old, 75-85 kg in dressed weight, deriving from the same farm and fed in the same way, was used. Muscle parts from the section covering the last two thoracic and the first three lumbar vertebrae were taken 24 hours after cooling of sides at 2-4°C. They were freed of visible fatty and connective tissues. Two ways of mechanical treatment were applied: intensive grinding, namely preparation of homogenates, and cutting into pieces (vertebrae-thick slices were cut into four equal parts), whereby 20% sodium chloride water solution was added or injected in the quantity of 10%. The following heat treatments were applied: pasteurization (200 g cans were kept in water at 80°C for about 30 minutes till the obtainment of 70°C in the can content center), sterilization (118°C/30 min., maximum temperature in the can content center - 115°C) and roasting (muscle pieces, being on the surface rubbed in with sodium chloride in the quantity of 1% on meat weight,were roasted in dish-shaped aluminium foils in drying oven at 180-200°C till the obtainment of 65-70°C in meat center).

The examinations were performed in raw meat and in samples taken immediately after mechanical and heat treatments and after storage for 3, 6, 9, 12 and 15 days at 2-3°C. From each experimental group six samples were examined. About 8 mm wide surface layer and the central part of roasted meat pieces were separately analysed. The same technique as described in the previous work (2) was used for determinations of phospholipid content, peroxide value, TBA number and free fatty acid content in total lipids, phospholipids and neutral lipids.

Mean value, standard deviation and variance coefficient were determined. Differences in the examined indices among samples treated by different mechanical and heat procedures during their storage were statistically evaluated (9).

Results and Discussion

The content of phospholipids decreased constantly in all samples during their storage (Table 1). The samples of homogenates always showed lower phospholipid content than meat pieces. The highest decrease of phospholipid content was observed after storage for 3 and 6 days. In the case of raw samples, differences in the phospholipid content between homogenates and meat pieces were significant after storage for 15 days, regardless of the way in which they were presented. In all examination periods, pasteurized and sterilized samples had significantly lower phospholipid content than raw samples being also mechanically treated. At the end of storage, the decrease of phospholipid content was somewhat higher in the surface layer than in the central part of roasted meat slices. These differences are significant if data are expressed on dry matter basis.

The lowest oxidation of lipids was registered during storage of raw meat pieces. Difference significance of peroxide value and TBA number between raw homogenates and meat pieces indicates considerably higher development of oxidative changes in homogenates (Table 2). These data evidently indicate that the exposure of larger surface to the activity of oxygen and the possibility of its incorporation into meat during intensive grinding results in momentary oxidative changes on occasion of grinding and relatively quick development during storage. Considerably higher content of free fatty acids in raw homogenates than in meat pieces points out that desintegration of meat structure formed more favourable conditions for the lypolysis as well, which continued during storage in the refrigerator.

Oxidation of lipids was developed very quickly in all heat treated samples during their storage, whereby the highest rate was obtained in pasteurized and then in sterilized homogenates, being of similar intensity in the surface layer of roasted meat slices. According to peroxide values and TBA numbers, oxidation in the central part of roasted meat pieces was expressed to somewhat higher extent than in pasteurized meat pieces. During storage at 2-3°C of heat treated samples, the lowest oxidation rate was observed in sterilized pieces, but still somewhat higher than in raw meat pieces. More intensive oxidative changes in heat treated samples than in raw samples being also mechanically treated can probably be explained by the increase in the amount of phospholipids and of polyunsaturated fatty acids in the free lipids caused by heat treatment (12) as well as by better diffusion of oxygen into heat treated tissue (6). The obtained results agree with the statement of Yamauchi (11) that higher TBA values are registered in pork in the case of processing at lower temperatures. However, our results are not in agreement with the statement of this author that TBA values are not increased in sterilized meat during storage for 4 days in the refrigerator. In addition, our results are in concordance with the results obtained by Tims and Watts (10), Watts (13), Keskinel et al. (6) and Wilson et al. (14) that heat treatment results in considerably higher TBA values of total lipids, but they disagree with their data on storage. However, it should be taken into consideration that the authors did not examine the changes of TBA values in samples processed by different mechanical and heat treatments and that they followed these changes only during 2-4 days of storage in the refrigerator.

On the basis of the established contents of phospholipids, neutral and total lipids in different periods of sample cooling as well as peroxide values, TBA numbers and free fatty acid contents in them, the data on the contribution of phospholipids and neutral lipids in oxidative and hydrolytic changes of lipids during storage were obtained (Table 3). From the table it can be seen that the contribution of phospholipids in peroxide value ranged from 73.12 to 89.78% and of neutral lipids from 10.22 to 26.88%. This contribution in TBA number was 86.12 to 94.62% for phospholipids and 5.38 to 13.88% for neutral lipids. This indicates that oxidative changes during meat storage are first of all the consequence of phospholipid oxidation. The percentage of phospholipid contribution in TBA number, and specially in peroxide value, was higher during the initial periods of examination, showing tendency to decrease during storage. These findings speak in favour of statements that phospholipids are oxidized first and then neutral lipids (5). Higher contribution in oxidation during the initial stages of storage is probably due to higher representation of phospholipids and their liability to oxydation. The contribution of phospholipids in free fatty acid content was 66.03 to 73.28% and of neutral lipids - 26.72 to 33.97%. During storage, this contribution of phospholipids showed tendency to increase, what can be explained by their decomposition.

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Changes of phospholipid content in samples during storage at 2 to 3°C, dependant on the way of mechanical and heat treatments

Table 1

Treatment	Days of storage						Treatments	Differences $\lvert d\bar{x} \rvert$					$\lvert d\bar{x}_{BM/DM} \rvert$
	0	3	6	9	12	15		3	6	9	12	15	
Mechanical treatment							a : b	0.005	0.006	0.004	0.005	0.008*	1.71*
a. Homogenate	0.552	0.530	0.512	0.497	0.487	0.473	a_1 : b_1	0.010	0.012*	0.010	0.011	0.017**	0,13
b. Meat pieces	0.557	0.535	0.518	0.501	0.492	0.481	a_2 : b_2	0.011	0.013	0.010	0.011	0.015*	0.10
Heat treatment							a_1 : a_2	0.007	0.007	0.006	0.006	0.004	0.78
1. Pasteurization							b_1 : b_2	0.006	0.006	0.006	0.006	0.006	1.01
a_1 Homogenate	0.530	0.510	0.492	0.474	0.467	0.449	a_1 : a	0.020***	0.022**	0.023**	0.020**	0.024***	0.92
b_1 Meat pieces	0.545	0.520	0.504	0.484	0.478	0.466	a_2 : a	0.027***	0.027**	0.029***	0,023**	0.028**	1.70**
2. Sterilization							b_1 : b	0.015***	0.014***	0.017***	0.014**	0.015***	2,50**
a_2 Homogenate	0.524	0.503	0.485	0.468	0.461	0.445	b_2 : b	0.021***	0.020**	0.023***	0.020**	0.021***	3.51***
b_2 Meat pieces	0.536	0.514	0.498	0.478	0.472	0.460	c_1 : b	0.038***	0.032**	0.028***	0.032**	0.022***	8.21***
3. Roasting							c_2 : b	0.048***	0.043***	0.038***	0.039***	0.035***	3.06***
c_1 Surface layer	0.598	0.573	0.550	0.529	0.524	0.503	c_1 : c_2	0.010***	0.011***	0.010***	0.007**	0.013***	5.15***
c_2 Central part	0.610	0.583	0.561	0.539	0.531	0.516	c_1 : b_1	0.053***	0.046***	0.045***	0.046***	0.037***	5.71***
							c_1 : b_2	0.059***	0.052***	0.051***	0.052***	0.043***	4.70***
							c_2 : b_1	0.063***	0.057***	0.055***	0.053***	0.050***	0.56
							c_2 : b_2	0.069***	0.063***	0.061***	0.059***	0.056***	0.45

$\bar{x}$ - mean value of phospholipid content, %

$\lvert d\bar{x} \rvert$ - absolute value of the difference of phospholipid content

$\lvert d\bar{x}_{BM/DM} \rvert$ - absolute value of the difference of phospholipid percentage in sample in relation to its quantity in raw meat (M), expressed on dry matter basis (DM)

*P ≤ 0.05 **P ≤ 0.01 ***P ≤ 0.001

Changes of peroxide value[1], TBA number[2] and free fatty acids[3] in samples during storage at 2 to 3°C, dependent on the way of mechanical and heat treatments[4]

Table 2.

Treatments	Differences $\lvert d\bar{x} \rvert$															
	peroxide value					TBA number					free fatty acids					
	3	6	9	12	15	3	6	9	12	15	3	6	9	12	15	
a : b	4.24*	5.06*	4.13*	5.75*	9.18*	3.83*	13.19*	12.70*	12.70*	11.80*	1.58*	1.32*	1.21*	0.97	1.35*	
a_1 : b_1	4.85*	6.34*	7.23*	5.30	5.11	6.25*	1.55*	12.90*	12.10*	11.54*	1.17*	1.11*	0.46	0.58	0.78	
a_2 : b_2	3.77*	4.91*	4.20*	3.95*	5.19*	6.78*	13.00*	12.39*	13.19*	9.10*	1.20*	0.82	0.14	0.35	0.76	
a_1 : a_2	0.53*	2.50*	1.93	3.90*	2.27	0.61	0.88	2.16*	2.07*	4.42*	0.03	0.01	0.37	0.55	0.66	
b_1 : b_2	1.42	0.60	0.87	0.92	1.60	1.14	2.33*	1.63	3.14*	1.58	0.00	0.29	0.69	0.78*	0.68	
a_1 : a	3.67*	2.63	4.62*	2.61	2.27	3.89*	1.43	1.72	3.82	5.17*	0.34	0.58	1.10	1.07	1.44**	
a_2 : a	1.17	0.70	0.72	0.34	0.75	3.28*	0.55	0.44	1.75	0.75	0.31	0.58	0.73	0.52	0.78	
b_1 : b	3.06*	1.45*	1.52	3.06*	6.32*	1.47	3.07*	5.11*	4.42*	4.63	0.07	0.37	0.35	0.68	0.89	
b_2 : b	1.64*	0.85	0.65	2.14	4.72*	0.33	0.74	3.48	1.26	3.05*	0.07	0.08	0.34	0.10	0.21	
c_1 : b	4.89*	4.48*	6.14*	9.27*	10.56*	9.41*	11.45*	12.54*	10.84*	10.40*	1.49*	0.57	0.74	0.47	0.32	
c_2 : b	3.47*	3.22*	4.52*	6.32	11.75*	7.76*	8.49*	10.48*	6.79*	5.78*	1.15*	0.27	0.42	0.28	0.07	
c_1 : c_2	1.22	1.26	1.22	2.95	1.19	1.63*	2.94	1.86	4.05*	4.62*	0.34	0.30	0.32	0.19	0.25	
c_1 : b_1	1.63	3.03*	4.62*	6.21*	4.24*	7.94*	8.34*	7.23*	6.42*	5.77*	1.42*	0.94*	1.09*	1.15*	1.21*	
c_1 : b_2	3.05*	3.63*	5.49*	7.13*	5.84*	9.08*	10.69*	8.86*	9.54*	7.35*	1.42*	0.65	0.40	0.37	0.53	
c_2 : b_1	0.41	1.77*	3.40*	3.26	5.43*	6.29*	5.42*	5.37*	2.37	1.15	1.08*	0.64	0.77*	0.96*	0.96	
c_2 : b_2	1.83	2.37**	4.27*	4.18*	7.05*	7.43*	7.75*	7.00*	5.53*	2.73*	1.08	0.35	0.08	0.18	0.28	

[1] meq peroxide oxygen/1000 g of lipids [2] mg malonaldehyde/1000 g of lipids [3] % oleic acid in 100 g of lipids

[4] letters a, b, a_1, b_1, a_2, b_2, c_1 and c_2 denote the same mechanical and heat treatments as in table 1.

*P ≤ 0.05 **P ≤ 0.01 ***P ≤ 0.001

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Contribution of phospholipids (%) in lipid oxidation and hydrolysis during storage of samples at 2 to 3°C

Table 3.

Days of storage	Homogenate						Meat pieces						Roasted meat			
	raw		pasterized		sterilised		raw		pasterized		sterilised		surface layer		central part	
	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v	$\bar{x}$	C_v
I. Peroxide value																
3	85.33	3.27	85.10	6.08	84.22	6.75	84.27	6.15	79.35	7.99	80.85	9.95	89.78	6.30	87.71	6.83
6	85.90	4.64	82.17	7.25	81.17	10.08	81.68	6.32	78.91	8.99	78.22	8.00	86.93	6.90	88.35	6.37
9	82.11	4.39	80.98	6.66	79.36	9.24	78.49	6.23	79.45	8.18	79.12	7.63	86.78	6.84	82.05	7.12
12	80.09	4.03	78.22	10.42	80.21	7.01	80.22	4.91	73.12	6.81	77.04	9.80	80.21	8.78	83.24	9.77
15	77.83	4.64	79.04	8.10	77.17	9.81	78.13	6.85	75.55	9.87	74.12	9.59	81.17	12.68	78.35	9.36
II. TBA value																
3	91.66	3.46	92.38	3.61	91.12	2.10	90.98	2.94	91.48	3.68	92.58	4.79	93.96	4.63	94.22	4.15
6	88.12	7.06	92.12	3.89	92.47	3.32	89.10	4.30	89.99	2.66	91.31	4.01	93.76	3.58	91.35	2.54
9	90.71	2.80	91.88	4.26	91.34	3.94	87.74	4.62	91.54	2.79	91.18	3.60	94.62	3.38	92.27	2.03
12	87.13	4.82	90.10	3.69	89.75	3.82	87.78	5.33	89.43	4.48	88.98	5.54	89.61	3.41	89.36	3.26
15	86.25	4.06	89.05	2.84	88.12	6.93	87.22	4.15	88.78	3.95	90.82	3.40	86.12	4.65	90.11	2.98
III. Free fatty acids																
3	67.05	7.91	68.81	4.98	68.60	9.03	66.03	12.42	68.03	7.45	66.33	10.57	69.03	5.57	66.72	8.58
6	68.75	5.36	68.12	5.49	67.92	7.43	67.13	7.34	67.56	8.60	68.93	6.02	68.78	6.49	68.82	6.37
9	71.12	4.06	70.95	8.29	70.85	2.76	69.72	5.93	71.93	3.33	68.55	6.03	69.48	3.76	70.73	6.38
12	70.38	8.98	69.14	6.28	72.43	3.49	69.37	5.45	69.93	4.41	72.45	3.47	72.19	5.57	73.01	4.36
15	73.01	3.43	72.25	3.93	73.28	2.26	72.09	3.16	71.35	4.06	71.98	3.56	71.46	4.83	72.11	4.30

$\bar{x}$ - mean value

C_v - variance coefficient