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FACTORS INFLUENCING PHYSIOLOGICAL PHOSPHORUS CONTENT IN PORK MEAT

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A b s t r a c t. New studies on the relationship between physiological phosphorus concentration and protein content were performed, involving well-characterised research material: elements of 36 carcasses of pigs differentiated in respect of gender, post-slaughter weight (PSW) and meatiness measured as the lean meat percentage (LMP), determined on the ground of dissection. The contents of total phosphorus (PC), crude protein (BC), collagen (CC) and muscular protein (BM = BC – CC) in meat were determined. It was found that determination of crude protein alone was not sufficient for prediction of natural phosphorus content in pork meat and its products. Satisfactory estimation of phosphorus content in pork meat based on crude protein and collagen content was obtained. Influence of carcass meatiness and post-slaughter weight of pigs on phosphorus content in meat was demonstrated and considered in the equation of estimating phosphorus content in meat. No effect of pig gender on phosphorus content in meat was found.

K e y w o r d s: pork meat, phosphorus content, protein content, meatiness, post-slaughter weight

INTRODUCTION

In food engineering dimensionless ratios are often used for comparing the unknown with well-known material or factor. For example, in meat technology ratios of different chemical components concentrations to protein concentration in animal tissues are successfully used for the characterisation and control of raw materials and products.

During the quality control of meat products, the content of the so-called phosphorus added (PA) is determined. It is added to meat as a food additive in the form of polyphosphate preparations. Its aim is to bind water and to improve the texture of the product. The analytical methods do not allow for differentiation between the added phosphorus and natural phosphorus content present in meat.

Since physiological phosphorus of animal tissues is a constituent of protein structures, its concentration in meat products may be estimated from the concentration of protein. In the Polish Standard, amended in 1999 (PN-A-82060), the percentage of phosphorus added to meat product (PA) is calculated from the following formula:

$$PA=2.29\ (PC - 0.01\ BC) \tag{1}$$

where:
PC – total phosphorus content, determined by analytical method;
BC – crude protein content, determined by Kjeldahl method, adopting the coefficient of protein nitrogen calculation into protein, being equal to 6.25;
2.29 – coefficient of phosphorus conversion into P_20_5.

The non-dimensional coefficient 0.01 was established as the mean of the results of experimental studies on phosphorus: protein content ratio conducted in the years 1990 -991 (Kłossowska and Tyszkiewicz 1992). In the mentioned studies, the following results were obtained for pork meat: ham muscles – 0.0104 (dark muscles) and 0.0101 (bright muscles), muscle longissimus dorsi (loin) – 0.0097, shoulder muscles – 0.0100, neck – 0.0101 and belly – 0.0095.

According to the information obtained from the industry, concerning the cases of calculation of the phosphorus content in products to which polyphosphates were certainly not added, it was decided to conduct new studies on the relationship between physiological phosphorus concentration and protein content, employing well-characterised research material, representing pigs from the country population with increased meatiness (Tyszkiewicz *et al.* 2005).

MATERIAL AND METHODS

Experimental material included 36 carcasses of pigs differentiated according to gender (15 hogs and 21 gilts), with post-slaughter weight (PSW) from 62.2 kg to 95.2 kg and meatiness from 43,5% to 59,8%, measured as the lean meat percentage (LMP), determined on the basis of dissection performed by the method of Walstra and Merkus (Walstra and Merkus 1996). The carcasses were divided into particular cuts: loin (ML), ham (MH), shoulder (MS), neck (N), belly (B), jowl (J), shoulder hock (HS) and leg hock (HL). The muscles of loin, ham and shoulder and the total of tissues of the remaining elements were subjected to tests, and the following determinations were performed: total phosphorus content (PC) – by weight method, after converting it to choline phosphomolybdate, crude protein content (BC) – by Kjeldahl method and collagen content (CC) – by hydroxyproline method. The content of muscular protein (BM) was calculated from the difference BC – CC, non-dimensional indices as the ratios total phosphorus content: crude protein content (PBC) = $PC \cdot BC^{-1}$

and ratios total phosphorus content: muscular protein content (PBM) = $PC \cdot BM^{-1}$, and percent of collagen content: crude protein content (CBC) = $(CC \cdot BC^{-1}) \times 100\%$.

RESULTS AND DISCUSSION

The results of chemical analyses revealed a lack of significant differentiation of particular cuts due to the gender of animals, which allowed showing them together in Table 1.

Table 1. Results of chemical analysis and calculated indicators

Parameters		Total Phosphorus Content	Crude Protein Content	Collagen Content	Relation $(CC \times BC^{-1}) \times 100\%$	Muscular Protein Content	Relation $PC \times BC^{-1}$	Relation $PC \times BM^{-1}$
Carcass Cuts		PC $\% \cdot 10^{-1}$	BC %	CC %	CBC %	BM %	PBC $(-) \cdot 10^{-2}$	PBM $(-) \cdot 10^{-2}$
Loin	$\bar{x}$	2.03	21.4	0.9	4.2	20.5	0.95	1.00
ML	S	0.06	1.2	0.2		1.3	0.05	0.05
Ham	$\bar{x}$	2.03	20.3	0.8	3.9	19.6	1.00	1.04
MH	S	0.09	1.2	0.1		1.2	0.06	0.06
Shoulder	$\bar{x}$	1.98	19.6	1.1	5.6	18.6	1.01	1.07
MS	S	0.07	1.0	0.2		1.2	0.05	0.06
Neck	$\bar{x}$	1.64	17.0	1.3	7.6	15.7	0.97	1.05
N	S	0.10	1.1	0.2		1.1	0.06	0.06
Belly	$\bar{x}$	1.14	14.8	3.1	20.9	11.7	0.76	0.98
B	S	0.12	1.5	0.5		1.5	0.09	0.08
Jowl	$\bar{x}$	1.22	13.7	2.3	16.8	11.4	0.88	1.07
J	S	0.17	1.6	0.5		1.8	0.08	0.09
Shoulder	$\bar{x}$	1.27	19.3	6.1	31.6	13.2	0.65	1.05
HS	S	0.06	0.7	0.9		0.9	0.05	0.05
Leg	$\bar{x}$	1.33	17.6	4.2	23.9	13.4	0.75	1.00
HL	S	0.06	0.8	0.7		0.8	0.04	0.06

It is easy to notice that with an increase of collagen content in meat the ratio of phosphorus content to crude protein content (PBC) is decreasing, which indicates that proteins of connective tissue do not bring or bring considerably less phosphorus to the system than muscular proteins. It also indicates that total protein content itself is not a parameter suitable for predicting phosphorus content in meat products. Much smaller differentiation and lack of any noticeable relationship of phosphorus to muscular protein ratio and collagen level allowed to consider that it would be easier to predict phosphorus content in meat based on the content of muscular protein (BM). This assumption was confirmed by a correlation calculated based on individual results of determination of phosphorus content (PC), crude protein content (BC) and muscular protein content (BM) for all the examined samples. The regression equations have the following form:

$$PC \times 100 = 1.04\ BC - 2.74 \qquad (2)$$

with coefficient of determination R^2 = 0.585 and standard error of estimation 0.0243%, and

$$PC \times 100 = 1.00\ BM + 3.40 \qquad (3)$$

with coefficient of determination R^2 = 0.907 and standard error of estimation 0.0115%.

Significantly higher coefficient of determination, R^2 = 0.930, and lower error of estimation - 0,0100% - are obtained when considering, beside the muscular protein, also the collagen content in equation (3). Then, the equation has the following equivalent forms:

$$PC \times 100 = 0.880\ BM - 0.385\ CC + 3.11 \quad \text{or} \qquad (4)$$

$$PC \times 100 = 0.880\ BC - 1.265\ CC + 3.11 \qquad (5)$$

It should be, however, mentioned that this equation, although being correct from the viewpoint of calculation, has a doubtful chemical sense as it is difficult to imagine “negative phosphorus” and such phosphorus would accompany collagen, occurring in connective tissue of meat. It may be assumed that the “minus” sign in the equation (4) results from natural highly significant negative correlation between muscular protein (BM) and collagen (CC) in different tissues constituting the composition of meat. It may be also discussed that the proteins of smooth muscles which accompany collagen in connective and fat tissue are also accompanied by other quantities of phosphorus than the proteins of striated skeletal muscles.

Attempts at finding confirmation of this hypothesis were conducted analysing the results of the studies on relationship between phosphorus content (PC) and muscular protein (BM) and collagen content (CC), performed for the particular cuts and their groups. When comparing PBM indices obtained for the particular

cuts, a significant differentiation of the mutual relationship was found. The percentage content of collagen in total protein (CBS) was assumed as the criterion. Two groups of elements were created: group I – including meat of loin, ham, shoulder and neck, and group II – consisting of the remaining elements, being more abundant in connective tissue (CBC>10%).
The following regression equations were obtained:

For group I

$$PC(I) \times 100 = 0.628\ BM - 1.34\ CC + 8.93 \quad (R^2 = 0.736) \qquad (6)$$

For group II

$$PC\ (II) \times 100 = 0.708\ BM - 0.10\ CC + 3.99 \quad (R^2 = 0.617) \qquad (7)$$

If we compare the constants of these two equations, we can state that the high absolute values and differences of more than one order of magnitude between negative coefficients of regression characterise the role of collagen content in the equation.

Estimation of phosphorus content for the whole experimental material with the application of equations (6) and (7) gave a positive effect with coefficient of determination $R^2 = 0.942$ and standard error of estimation of 0.0091%.
Statistically significant effect of meatiness LMR and post-slaughter weight of carcass PSW on total phosphorus content PC and PBM index was found.

The above mentioned factors decrease the value of the index and are responsible for 6.7% of variability for group I and 4.9% for group II, and for 5.2% of variability for both groups considered in total. The equations of multiple regression, as calculated including all examined factors, reveal a significant effect on phosphorus content in pork meat for both groups of elements and have the following form:

$$PC(I) \times 100 = 0.630\ BM - 1.39\ CC - 0.016\ PSW + 10.2 \quad (R^2 = 0.742) \qquad (8)$$

$$PC\ (II) \times 100 = 0.721\ BM - 0.11\ CC - 0.013\ PSW + 5.1 \quad (R^2 = 0.624) \qquad (9)$$

Meatiness (LMP) turned out to be a factor which did not have any statistically significant effect on phosphorus content. This fact shows that the influence on PBM index existed in the rise of muscular protein in the meat. Estimation of phosphorus content for the whole experimental material with the application of equations (8) and (9) describes 93.2% of variability with standard error of estimation of 0.0098%.

The universal equation for predicting the physiological content in pork meat, being detailed in the equation (4), has the following form:

$$PC \times 100 = 0.895\ BM - 0.366\ CC - 0.026\ LMP - 0.018\ PSW + 5.78 \quad (10)$$

It explains 93.3% of the variability with standard error of estimation equal to 0.0098%, and takes into account all the factors that have a statistically significant effect on phosphorus content.

CONCLUSIONS

1. No effect of pig gender on phosphorus content in meat was found.
2. Variability of phosphorus content in meat of particular elements of carcass was found, making univocal estimation of phosphorus content on the basis of protein analysis possible.
3. It was found that determination of crude protein content alone was not sufficient for predicting the physiological phosphorus content in pork meat and its products.
4. Satisfactory estimation of physiological phosphorus content in pork meat was found based on muscular protein or on crude protein content and collagen content, considered together but separately treated.
5. Influence of carcass meatiness and post-slaughter weight of pigs on relative and absolute phosphorus content in meat was demonstrated and considered in the universal equation of estimating physiological phosphorus content in meat.

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CZYNNIKI WPŁYWAJĄCE NA ZAWARTOŚĆ FOSFORU FIZJOLOGICZNEGO W MIĘSIE WIEPRZOWYM

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Streszczenie. Przeprowadzono nowe badania zależności zawartości fizjologicznego fosforu od zawartości białka w mięsie świń zróżnicowanych pod względem płci, i dobrze scharakteryzowanych pod względem ciężaru ubojowego (PSW) oraz mięsności określonej dysekcyjnie na podstawie zawartości chudego mięsa w tuszy (LMP). Badano zawartości w mięsie całkowitego fosforu (PC), białka ogólnego (BC), kolagenu (CC), oraz białka mięśniowego (BM)= BC – CC. Stwierdzono że oznaczenie samego białka ogólnego nie pozwala na dobre oszacowanie zawartości fizjologicznego fosforu w mięsie świń i w jego przetworach. Zadawalające oszacowanie zawartości fosforu w mięsie uzyskano w oparciu o oznaczoną zawartość białka ogólnego i kolagenu. Wykazano statystycznie istotny wpływ ciężaru ubojowego świń i mięsności tusz na zawartość fosforu w mięsie i uwzględniono go w uniwersalnym równaniu opisującym 93,3% zmienności zawartości fosforu w mięsie ze standardowym błędem oszacowania 0,0098%. Nie stwierdzono wpływu płci świń na zawartość fosforu w mięsie.

Słowa kluczowe: mięso świń, zawartość fosforu, zawartość białek, mięsność, ciężar ubojowy