

Polymorphism of blood protein and meat quality of pigs from a mass population

Koćwin-Podsiadła Maria¹, Jolanta Kurył² and W. Przybylski¹

¹*Agriculture Pedagogical High School, Prusa 12, 08-110 Siedlce, ²Institute of Animal Genetics and Breeding, Jastrzębiec, 05-551 Mroków, Poland*

(Received 20 January 1992; accepted 1 June 1992)

ABSTRACT

The investigations carried out on 626 growing pigs were designed to differentiate the extent to which the decreased quality of their meat resulted from the environmental conditions and that to which it was due to the genetic predispositions of the animals. The latter were evaluated on the basis of the presence of the Phi, Po2 and Pgd genes linked with the gene of halothane susceptibility to stress. The quality classes of meat were estimated by measurements of pH₁ and the IMP/ATP ratio (R₁). The genotypes of the animals were determined on the basis of blood erythrocyte enzymes, phosphohexoisomerase (Phi) and phosphogluconate dehydrogenase (Pgd) and of the blood plasma protein, postalbumin-2 (Po2). There were 283 Phi^B-Po2^S-Pgd^A and Phi^B-Po2-Pgd^B haplotypes which amounted to 22.6% of their total number. The frequency of occurrence of the two haplotypes specified above in the configuration Phi-Po2-Pgd was the highest in pigs producing the PSE type of meat (45.7%), lower in animals with the DFD type of meat (30.3%) and the lowest in the group of pigs with normal meat (17.2%). Animals which produced PSE and DFD meat amounted to 37% of the examined population, whilst among them, 31.8% demonstrated genetic predispositions to meat defects.

KEY WORDS: pigs, stress, meat quality

INTRODUCTION

Susceptibility of pigs to stress is a genetically determined characteristic. Most frequently it is examined by the halothane test, i.e. inhalation performed with a mixture of the anaesthetic halothane (fluothane) and oxygen. For that reason the gene determining susceptibility to stress has been called halothane gene. Another method of assessing genetic susceptibility to stress is based on the determination of blood protein polymorphism. Genes which determine this polymorphism are located on the same chromosome as the halothane gene acid in its immediate vicinity (Archibald and Imlah, 1985). The non-random occurrence of certain protein types together with the halothane gene (Halⁿ) is

a consequence of that linkage. It has been found that over 80% of animals homozygotic for that allele demonstrate PSE and DFD meat (Barton-Gade and Olsen, 1987). On the other hand it is possible to predict with highly significant probability the occurrence of abnormal muscle tissue on the basis of haplotypes, i.e. of certain configurations of alleles in the system of linked loci Phi-Po2-Pgd. The haplotypes Phi^B-Po2^S-Pgd^A and Phi^B-Po2^S-Pgd^B are of particular importance to making prognoses (Koćwin-Podsiadła et al., 1989).

The purpose of this paper was to study to what extent the quality of pig meat depends on the genetic predispositions estimated by the frequency of genes linked with the stress susceptibility gene and to what extent it results from the unfavourable influence of many environmental factors.

MATERIAL AND METHODS

The experiments were carried out on 626 pigs selected at random from agricultural farms in the region of breeding and production of the Polish Landrace in the eastern part of Poland. The animals were transported to the slaughter-house from distances of about 40-80 kilometres. The commercial pre- and slaughter procedure was as follows: resting time prior to slaughter: 24 h; stunning with electric current 160-220 V, 0.5 to 0.8 A and 2500 Hz during 8 ± 2 sec.; time from stunning to the start of bleeding (in hanging position) up to 40 sec. Samples of peripheral blood were taken during slaughter and of the muscle tissue from the longissimus dorsi muscle, behind the last thoracic vertebra. The genotypes of the animals in regard to the genes which control blood proteins - phosphohexoisomerase (Phi), phosphogluconate (Pgd) and postalbumin-2 (Po2) were determined by the electrophoretic technique of Gahne and Junei (1985).

The quality of fresh meat was evaluated by the inosine monophosphate/adenosine triphosphate nucleotide ratio IMP/ATP (R_1), as reported by Honikel and Fischer (1977), and by the measurement of the value 45 minutes „post-mortem”. Quality classes of meat were based on the border values for the pH_1 and R_1 criteria, according to the Honikel and Fischer (1977) method, modified by Koćwin-Podsiadła et al. (1988):

quality class of meat	pH_1	R_1
PSE	<6.0	≥ 1.092
partially PSE	<6.0	<1.092
normal	≥ 6.0	<1.092
DFD	≥ 6.0	≥ 1.092

The genetic equilibrium of the experimental material was determined according to the Hardy-Weinberg law. The number of pigs with the determined

Phi-Po2-Pgd haplotypes in which the abnormal meat was found was expressed as a percentage.

RESULTS AND DISCUSSION

The mean values of the characteristics used as quality criteria of porcine meat and the frequency of occurrence of animals having abnormal muscle tissue are presented in Table 1. Of the 626 experimental animals, 37.2% demonstrated meat

TABLE 1

Mean values and standard deviation of meat quality traits in pigs (n = 626)

Traits	Meat class			
	PSE	Partial PSE	Normal	DFD
No of pigs	47	110	393	76
pH ₁	5.69 ± 0.20	5.77 ± 0.17	6.37 ± 0.22	6.33 ± 0.22
R ₁	1.238 ± 0.09	0.961 ± 0.06	0.891 ± 0.07	0.183 ± 0.07

with PSE and DFD symptoms. This percentage is similar to that found by many authors in pigs from various parts of Poland as well as in pigs bred in the same region (Koćwin-Podsiadła and Kurył, 1990). From the genetic point of view the experimental material was in equilibrium as described by the Hardy-Weinberg law (Table 2).

TABLE 2

The distribution of phenotypes Phi, Po2 and Pgd in pigs classified according to meat quality

Locus	Pheno- types	Meat class							
		PSE		Partial PSE		Normal		DFD	
		observed/ expected	χ ²	observed/ expected	χ ²	observed/ expected	χ ²	observed/ expected	χ ²
Phi	A	0/ 0.80		2/ 1.33		10/ 8.84		2/ 1.09	
	AB	12/10.63	0.98	20/21.54	0.46	97/100.22	0.27	14/16.05	1.04
	B	35/35.57		88/87.13		286/283.94		60/58.85	
Po2	F	14/12.71		57/55.45		252/251.52		36/33.10	
	FS	21/23.46	0.52	43/45.30	0.24	127/125.76	0.20	29/34.11	1.58
	S	12/10.83		10/ 9.25		14/ 15.72		11/ 8.78	
Pgd	A	11/12.12		37/37.00		125/123.24		16/16.79	
	AB	26/23.49	0.53	53/53.59	0.02	189/193.67	0.25	40/37.86	0.23
	B	10/11.28		20/19.40		79/76.08		20/21.35	

The analysis of frequency of alleles which control the polymorphism of blood proteins Phi, Po2 and Pgd, determined by genes linked with the halothane gene revealed that allele Po2^S differentiated the particular quality classes of meat to

TABLE 3

The distribution of alleles Phi, Po2 and Pgd among animals classified according to meat quality

Allele	Meat quality				
	PSE n=47	Partial PSE n=110	Total PSE+part.PSE n=157	Normal n=393	DFD n=76
Phi ^A	0.13	0.11	0.11	0.15	0.12
Phi ^B	0.87	0.89	0.89	0.85	0.88
Po2 ^F	0.52	0.71	0.66	0.80	0.66
Po2 ^S	0.48	0.29	0.34	0.20	0.34
Pgd ^A	0.51	0.58	0.56	0.56	0.47
Pgd ^B	0.49	0.42	0.44	0.44	0.53

TABLE 4

The distribution of blood protein haplotypes Phi, Po2, Pgd in relation to meat quality

Haplotypes Phi-Po2-Pgd	Meat quality									
	PSE		Partial PSE		Total PSE+part. PSE		Normal		DFD	
	n	%	n	%	n	%	n	%	n	%
AFA	6	6.38	16	7.27	22	7.00	67	8.52	6	3.95
AFB	4	4.25	4	1.82	8	2.55	30	3.82	7	4.61
ASA	—	—	3	1.36	3	0.96	7	0.89	1	0.66
ASB	2	2.13	1	0.45	3	0.96	13	1.65	4	2.63
BFA	27	28.72	84	38.18	111	35.35	314	39.95	46	30.26
BFB	12	12.76	53	24.09	65	20.70	220	27.99	42	27.63
BSA	15	15.96	24	10.91	39	12.42	51	6.49	19	12.50
BSB	28	29.79	35	15.91	63	20.06	84	10.69	27	17.76
Total	94	100	220	100	314	100	786	100	152	100

the greatest extent (Table 3). The frequency of that allele was the highest in the group of pigs with PSE meat and it was more than double the frequency found in pigs with normal meat. In animals of inferior meat quality the frequency of that allele was nearly two times higher in comparison with animals of normal meat. Haplotypes, i.e. appropriate configurations of alleles relating to three linked loci Phi-Po2-Pgd in groups of pigs of various meat quality were estimated in the further course of this study (Table 4). It was found that the frequency of some haplotypes Phi-Po2-Pgd was typical for certain groups of animals. This was mainly so with haplotypes Phi^B, Po2^S, Pgd^A, Phi^B, Po2^S and Pgd which are linked with the halothane gene (Archibald and Imlah, 1985; Hojny et al., 1985) and lower meat quality (Koćwin-Podsiadła et al., 1989). Those haplotypes are referred to in short as BSA and BSB in the further part of this paper. Their frequency in the group of animals with PSE and DFD symptoms in meat was

found to be about 45% and 30%, respectively, and this is about 2-3 times higher than in pigs with normal meat. BFA and BFB haplotype frequencies did not differentiate the animals in relation to their predisposition for production of meat of low technological value since they attained about 50% in the examined groups (PSE and DFD). The AFA, AFB, ASA and ASB haplotypes demonstrated a low usefulness in predicting the quality of meat due to their low frequency in the experimental material. The lack of linkage of the specified haplotypes with the occurrence of abnormal meat in pigs was found also in the study of Koćwin-Podsiadła et al.(1989).

Among the 1252 identified Phi-Po2-Pgd haplotypes, a total of 283 BSA and BSB haplotypes were found and they were linked to a highly significant degree with the occurrence of abnormal meat: that figure constituted 22.6% of all of the identified haplotypes (Table 5, point 6). In the group of animals which showed meat with PSE and DFD defects (37% of the examined population), 31.8% demonstrated genetic predispositions (Table 5, point 4). The frequency BSA and BSB haplotypes was the highest in pigs with PSE meat (45.7%), slightly lower with PFD meat (30.3%) and the lowest in pigs with normal meat (17.2%). In the total number of BSA and BSB haplotypes, 52% were found in the group of animals demonstrating PSE or DFD type of meat (Table 5, point 4).

TABLE 5

The number of pigs in particular meat quality groups in comparison with the frequency of blood protein haplotypes Phi-Po2-Pgd linked with the halothane gene

Indices		PSE	Partial PSE	DFD	Abnormal PSE + part. PSE + DFD	Normal	Total
		1	2	3	4	5	6
Number of pigs	n	47	110	76	233	393	626
	%	7.51	17.57	12.14	37.22	62.78	100
Number of particular haplotypes	n	94	220	152	466	786	1252
	%	7.51	17.57	12.14	37.22	62.78	100
Frequency of BSA and BSB haplotypes in the particular meat classes	n	43	59	46	148	135	283
	%	45.75	26.82	30.26	31.76	17.20	22.60
Frequency of BSA and BSB haplotypes in comparison with the total number of these haplotypes	n	43	59	46	148	135	283
	%	15.20	20.85	16.25	52.30	47.70	100

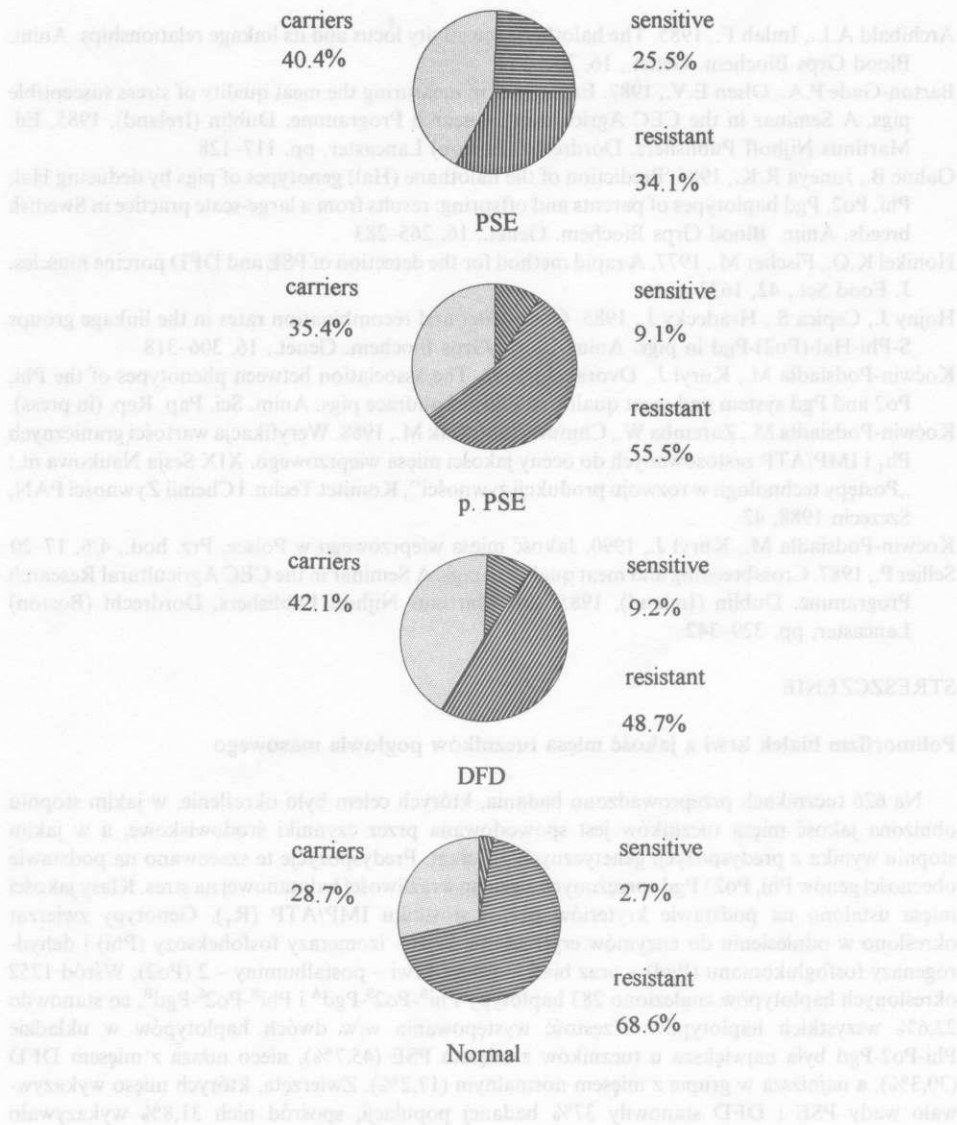
However, it should be emphasized that 466, i.e. 37.2% Phi-Po2-Pgd haplotypes were found in pigs with abnormal meat and the remaining 62.8% in pigs with meat of normal quality (Table 5, point 4 and 5, respectively).

One hundred forty eight, i.e. 52.3% of the total number of BSA and BSB haplotypes, were found in the smaller group of pigs which demonstrated abnormal meat (Table 5, point 4). If the same proportion of BSA and BSB haplotypes would appear in all groups of animals, the percentage of haplotypes in the group of pigs with abnormal meat should be respectively lower, i.e. about 30%. This relationship is better confirmed in the experimental findings presented in Figure 1. Among pigs with PSE meat the highest percentage was found in animals having only BSA and BSB (25.5%) haplotypes, i.e. ten times higher than in the group of pigs with normal meat (2.7%). In the other groups of pigs with abnormal meat (partially PSE or DFD), the number of animals in which only the BSA and BSB haplotypes were identified was more than three times higher in comparison with animals with normal meat (Figure 1). In the group of animals with BSA and BSB haplotypes, there were both stress susceptible and stress resistant pigs.

The haplotypes BSA and BSB may be regarded as typical for pigs having abnormal meat, whereas the BSA and BSB haplotypes had similar frequency in all groups of the examined animals, regardless of the quality of meat (Table 4). If the „carrier” of the BSA or BSB haplotypes has as its second one the BFA or BFB haplotype linked with the haplotype gene Halⁿ, then it is probable that abnormal meat will be produced by such an animal. On the other hand, if the BFA or BFB haplotype is not linked with the halothane gene but with the gene dominant to Halⁿ, the meat in this case will, most probably, have normal properties. It was found that in heterozygotes Hal^NHalⁿ, who are carriers of the recessive Halⁿ allele, lower meat quality was not observed (Sellier, 1987).

CONCLUSIONS

1. Among alleles linked with the halothane gene, the Po2^S allele is the most useful in predicting the quality of porcine meat.
2. The haplotypes BSA and BSB occur with a several times higher frequency in animals having abnormal meat over those with normal meat.
3. Among all Phi-Po2-Pgd haplotypes, the BSA and BSB haplotypes demonstrate the highest usefulness in predicting porcine meat quality since more than half of their total number (52.3%) has been found in animals with abnormal meat.
4. Meat obtained from 37% of the examined animals showed PSE and DFD defects and one third of that group demonstrated genetic predispositions.



where:

sensitive – animals with the following haplotypes: BSA/BSB, BSB/BSB, BSA/BSA

carriers – animals with the following haplotypes:

- a) BSA/other from Po2F or PhiA,
- b) BSB/other from Po2F or PhiA,

resistant – animals lacking haplotypes BSA and BSB

Fig. 1 The frequency of specimens with specific haplotypes among animals classified according to meat quality

REFERENCES

- Archibald A.L., Imlah F., 1985. The halothane sensitivity locus and its linkage relationships. *Anim. Blood Grps Biochem. Genet.*, 16, 253–333
- Barton-Gade P.A., Olsen E.V., 1987. Experience in measuring the meat quality of stress susceptible pigs. A Seminar in the CEC Agricultural Research Programme, Dublin (Ireland), 1985, Ed. Martinus Nijhoff Publishers, Dordrecht (Boston) Lancaster, pp. 117–128
- Gahne B., Juneya R.K., 1985. Prediction of the halothane (Hal) genotypes of pigs by deducing Hal, Phi, Po2, Pgd haplotypes of parents and offspring: results from a large-scale practice in Swedish breeds. *Anim. Blood Grps Biochem. Genet.*, 16, 265–283
- Honikel K.O., Fischer M., 1977. A rapid method for the detection of PSE and DFD porcine muscles. *J. Food Sci.*, 42, 1633–1636
- Hojny J., Cepica S., Hradecky J., 1985. Gene order and recombination rates in the linkage groups S-Phi-Hal-(Po2)-Pgd in pigs. *Anim. Blood Grps Biochem. Genet.*, 16, 306–318
- Koćwin-Podsiadła M., Kurył J., Dvorak J., 1992. The association between phenotypes of the Phi, Po2 and Pgd system and meat quality in Polish Landrace pigs. *Anim. Sci. Pap. Rep.* (in press)
- Koćwin-Podsiadła M., Zaremba W., Chmura-Janowiak M., 1988. Weryfikacja wartości granicznych Ph_1 i IMP/ATP zastosowanych do oceny jakości mięsa wieprzowego. XIX Sesja Naukowa nt.: „Postępy technologii w rozwoju produkcji żywności”, Komitet Techn. i Chemii Żywności PAN, Szczecin 1988, 42
- Koćwin-Podsiadła M., Kurył J., 1990. Jakość mięsa wieprzowego w Polsce. *Prz. hod.*, 4/6, 17–20
- Sellier P., 1987. Crossbreeding and meat quality in pigs. A Seminar in the CEC Agricultural Research Programme, Dublin (Ireland), 1985, Ed. Martinus Nijhoff Publishers, Dordrecht (Boston) Lancaster, pp. 329–342

STRESZCZENIE

Polimorfizm białek krwi a jakość mięsa tuczników pogłowia masowego

Na 626 tucznikach przeprowadzono badania, których celem było określenie, w jakim stopniu obniżona jakość mięsa tuczników jest spowodowana przez czynniki środowiskowe, a w jakim stopniu wynika z predyspozycji genetycznych zwierząt. Predyspozycje te szacowano na podstawie obecności genów Phi, Po2 i Pgd sprzężonych z genem wrażliwości halotanowej na stres. Klasy jakości mięsa ustalono na podstawie kryteriów pH_1 i stosunku IMP/ATP (R_1). Genotypy zwierząt określono w odniesieniu do enzymów erytrocytów krwi – izomerazy fosfoheksosy (Phi) i dehydrogenazy fosfoglukonianu (Pgd) – oraz białka osocza krwi – postalbuminy – 2 (Po2). Wśród 1252 określonych haplotypów znaleziono 283 haplotypy $Phi^B-Po2^S-Pgd^A$ i $Phi^B-Po2^S-Pgd^B$, co stanowiło 22,6% wszystkich haplotypów. Częstość występowania w/w dwóch haplotypów w układzie Phi-Po2-Pgd była największa u tuczników z mięsem PSE (45,7%), nieco niższa z mięsem DFD (30,3%), a najniższa w grupie z mięsem normalnym (17,2%). Zwierzęta, których mięso wykazywało wady PSE i DFD stanowiły 37% badanej populacji, spośród nich 31,8% wykazywało predyspozycje genetyczne.