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Relationships between *GPI* and *PGD loci* genotypes and selected meat quality traits in Duroc and Pietrain pigs

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The results of statistical analysis appeared inconclusive as to which allele of the *GPI locus* could significantly affect the traits of meat quality, but higher meat pH_{45} values have been observed in animals with the $GPI^{B/B}$ genotype in both the Duroc and Pietrain breed. For meat pH_{24}, the $GPI^{A/B}$ genotype appeared to be more favourable, although not significantly. Beneficial effect on the meat colour traits was observed in Pietrain pigs having the GPI^{A} allele in their genotype. The meat of animals of the $GPI^{A/B}$ genotype was characterized by smaller lightness (L), greater redness and less intense yellowness. In addition, per cent of free water (WHC) was lower in animals with the GPI^{A} allele in their genotype, both in Pietrain and Duroc pigs.

Statistical analysis of meat quality traits at the *PGD locus* showed a small difference in pH_{45} in Duroc pigs. The best results with regard to this trait were found in animals of the $PGD^{B/B}$ genotype. For other traits, no differences were observed between the *PGD locus* genotypes. It is concluded that the *PGD* gene polymorphism does not affect the meat quality traits in pigs.

KEYWORDS: gene polymorphism / genetic markers / *GPI* / meat quality / *PGD* / pigs

Breeding efforts in the past were directed at improvement of muscling and fattening traits of pigs. This ensured considerable progress in carcass muscling, but adversely affected the quality of meat. Further breeding work must be aimed at improving both muscling and meat quality. Breeding programmes which were used for this purpose were based on multitrait or index selection accounting for meat quality traits, such as

pH, intramuscular fat content and meat colour. However, these efforts did not lead to the desired improvement of meat quality. This goes to show that the issue of meat quality is difficult to define and is affected by several unknown factors.

Modern techniques of molecular genetics resulted in the localization of the *RYR1* (ryanodine receptor) gene among others. Although it has positive effect on meat traits, the gene adversely affects meat quality by being responsible for PSE meat condition. For this reason, selection efforts were concentrated on eliminating the recessive $RYR1^{T/T}$ allele responsible for PSE fault from the pig population. Kurył *et al.* [2000] reported that about 80% of pigs with the $RYR1^{T/T}$ genotype showed PSE meat. This means, that in addition to the *RYR1* gene, meat quality traits are encoded by some other unknown genes [Kurył 1998]. Efforts are continued to identify genes controlling these traits. The discovery of genes controlling the increase in carcass muscling without negative effects on meat quality would be highly valuable for breeders. Today much research is focused on genes controlling polymorphism of two erythrocyte enzymes – glucosephosphate isomerase (gene *GPI*) and phosphogluconate dehydrogenase (gene *PGD*), which form the halothane linkage group together with the *RYR1* gene. This stimulated us to determine the effect of the *GPI* and *PGD* gene alleles on meat quality traits in pigs.

Material and methods

The study included Duroc and Pietrain gilts, evaluated at Slaughter Pig Testing Stations (SKURTCh) in Mełno and Pawłowice over years 2000-2002. A total of 220 gilts were studied, of which 99 were Duroc and 121 Pietrain. Animals were kept, fed, slaughtered and dissected according to the current methods applied at SKURTCh stations [Różycki 1996]. Prior to slaughter, blood was withdrawn from all animals to genotype them for the *GPI* and *PGD* genes. The results of these analyses served as a basis for further statistical calculations aimed to determine the effect of certain genotypes of particular genes on selected performance traits.

The following meat quality traits were analysed: pH measured 45 min and 24 h *post mortem* (pH_{45} and pH_{24}, respectively), meat colour (L, a and b values) and water holding capacity (WHC).

Meat pH was measured using a device equipped with a glass spearhead pH electrode (Mathäus, Germany), pH_{45} in the loin muscle over the last rib, off the midback, while pH_{24} at the cross-section of the *longissimus dorsi* muscle at three points along the cross-section. The result is a mean of three measurements. WHC holding capacity, determined using the Grau-Hamm method, is expressed by percentage of free water. Parametres of meat colour, *i.e*. lightness, redness and yellowness were expressed in the L (colour lightness) system: a^* (redness); b^* (yellowness) using Minolta apparatus type CR 310.

The erythrocyte enzymes – glucosephosphate isomerase (GPI) and phosphogluconate dehydrogenase (PGD) were genotyped by 1% agarose gel electrophoresis according to Gahne and Juneja [1985] in laboratory at Pawłowice.

The results were analysed statistically to identify the effect of individual *GPI* and *PGD loci* alleles on traits considered. Significance of differences between means was evaluated with Duncan's multiple range test. Calculations were made using the STATGRAPHICS package.

Results and discussion

Frequencies of genotypes at the *GPI* and *PGD loci* are presented in Table 1. Analysis of the *GPI locus* genotypes showed the low frequency of animals with the genotype $GPI^{A/A}$, amounting to 0.0248 in Pietrain gilts. No animals with this genotype were found among Durocs. The highest and almost identical frequency in both breeds was observed for the $GPI^{B/B}$ genotype (0.7895 and 0.7273 for Duroc and Pietrain, respectively. A similar frequency of the $GPI^{B/B}$ genotype in Pietrain pigs (74.8%) was reported by Bigi *et al.* [1991]. This genotype was also highly frequent (90.4%) in other populations of Pietrain pigs [Reinecke and Kalm 1988]. Vogeli *et al.* [1984], Grashorn and Muller [1985] and Reinecke and Kalm [1998] found the $GPI^{B/B}$ genotype to be the most frequent (78 to 90%) in the Landrace breed, with no animals of the $GPI^{A/A}$ genotype; frequency of genotypes at the *PGD locus* was not studied. In the present study the Pietrain breed was characterized by the low frequency of the $PGD^{B/B}$ genotype (0.1239), while in Durocs $PGD^{B/B}$ genotype was most frequent (0.7663). The proportions of animals with $PGD^{A/A}$ and $PGD^{A/B}$ genotypes were similar. Studies by Bigi *et al.* [1991] on Duroc pigs demonstrated that the frequency of the $PGD^{B/B}$ genotype assumes values above 50%. In this study the frequency of the $PGD^{B/B}$ genotype in Pietrain pigs was 12.4% (Tab. 1) being similar to the data obtained by Reinecke and Kalm [1998] for the same breed.

Table 1. Frequency of *GPI* and *PGD locus* genotypes in Duroc and Pietrain pigs

Locus	Genotype	Breed	
		Duroc	Pietrain
GPI	*AA*	–	0.0248
	BB	0.7895	0.7273
	AB	0.2105	0.2479
PGD	*AA*	0.1298	0.3884
	BB	0.7663	0.1239
	AB	0.1039	0.4877

Many reports claim that selection aimed at increasing carcass muscling, *i.e.*meat content of carcass may compromise meat quality. The increasing muscling of fatteners is accompanied by some defects that limit the processing capacity of meat. In Poland, pork quality problems emerged after importing of pig breeds characterized by high meat content of carcass. At that time the slaughter and meat quality traits of pigs were compared

between foreign breeds (Belgian Landrace, Duroc) and native breeds (Polish Large White, Polish Landrace). The results obtained indicate that crossbreeding of Belgian Landrace with Polish breeds for improved carcass muscling has an adverse effect on meat quality. Studies of Polish Large White, Polish Landrace, Pietrain, Hampshire, Duroc and Line 990 pigs at testing stations [Orzechowska *et al.* 1996] showed that practically only the Pietrain breed differed in meat quality from other breeds. Within each breed studied, some animals showed pH_{45} of meat to be below 5.8. The share of such animals was 15% of the population of PLW, 20% for PL, 5% for Duroc, and 13% for Line 990. For the Pietrain breed, pH_{45} below 5.8 was observed in 57% of the animals.

Researchers have given relatively little attention to the *GPI* and *PGD locus* genotypes and their effects on meat quality traits. This is why the present study was designed to investigate the effect of different alleles of the *GPI* and *PGD loci* on meat quality traits. The results of statistical analysis (Tab. 2) are inconclusive as to which allele of the *GPI locus* could significantly affect the traits of meat quality. It is true that higher pH_{45} values of meat were observed in animals with the $GPI^{B/B}$ genotype, both in the

Table 2. Means and standard deviations (SD) of particular genotypes of the *GPI* gene in Duroc and Pietrain pigs for meat quality traits

Trait	Breed		Genotype		
			A/A	*B/B*	*A/B*
Meat quality					
pH_1	Duroc	mean	–	6.48	6.44
		SD		0.41	0.30
	Pietrain	mean	5.62	5.85	5.48
		SD	0.62	0.32	0.51
pH_2	Duroc	mean	–	5.51	5.53
		SD		0.08	0.11
	Pietrain	mean	5.39	5.43	5.47
		SD	0.10	0.11	0.12
water holding capacity	Duroc	mean	–	32.4	30.4
		SD		5.23	4.25
	Pietrain	mean	–	41.5*	34.9*
		SD		7.20	6.36
lightness "L"	Duroc	mean	–	55.1	55.2
		SD		3.15	3.66
	Pietrain	mean	–	59.1*	54.5*
		SD		2.82	3.53
redness "a*"	Duroc	mean	–	14.36	14.44
		SD		1.84	1.68
	Pietrain	mean	–	15.00*	16.45*
		SD		1.06	0.69
yellowness "b*"	Duroc	mean	–	4.76	5.46
		SD		2.19	2.38
	Pietrain	mean	–	6.52*	5.07*
		SD		0.99	0.74

Duroc and Pietrain breed, but the differences were not found significant. For pH_{24} of meat, the $GPI^{A/B}$ genotype appeared to be more favourable, although not significant as well. As regards the other meat quality traits, significant differences were observed only in Pietrain pigs. In this breed, the presence of the GPI^{A} allele had a beneficial effect on meat colour traits. Meat of animals with the $GPI^{A/B}$ genotype was characterized by smaller lightness (L), greater redness and less intense yellowness. Moreover, WHC was much lower in animals with the GPI^{A} genotype, both in the Pietrain and Duroc pigs. Reinecke and Kalm [1988] demonstrated that both the GPI^{A} and PGD^{A} alleles have a beneficial effect on meat colour. Glodek *et al.* [1985] and Vogeli *et al.* [1984] showed a beneficial effect of these alleles on pH of meat.

The results of statistical analysis of meat quality traits for the *PGD locus* are presented in Table 3. A small but favourable difference in pH_{45} of meat was found in Duroc pigs with the $PGD^{B/B}$ genotype. For remaining traits, no significant differences between the *PGD locus* genotypes were observed. Therefore, it can be concluded that the *PGD* gene has no effect on meat quality traits.

Our results and those of other authors may suggest that in a population of pigs

Table 3. Means and standard deviations (SD) of particular genotypes of the *PGD* gene in Duroc and Pietrain pigs for meat quality traits

Trait	Breed		Genotype A/A	Genotype B/B	Genotype A/B
Meat quality					
pH_5	Duroc	mean	6.45	6.49	6.37
		SD	0.49	0.37	0.35
	Pietrain	mean	5.58	5.49	5.59
		SD	0.37	0.25	0.47
pH_{45}	Duroc	mean	5.51	5.51	5.53
		SD	0.08	0.09	0.11
	Pietrain	mean	5.45	5.44	5.44
		SD	0.12	0.07	0.12
water holding capacity	Duroc	mean	31.5	31.9	33.0
		SD	2.98	5.31	5.41
	Pietrain	mean	39.8	39.6	40.1
		SD	7.37	4.29	8.81
lightness "L"	Duroc	mean	54.8	55.2	54.2
		SD	1.64	3.38	3.49
	Pietrain	mean	59.3	59.6	58.2
		SD	4.61	4.17	3.19
redness "a*"	Duroc	mean	14.72	14.21	15.21
		SD	1.29	1.87	1.51
	Pietrain	mean	14.93	14.64	15.66
		SD	1.39	1.08	0.96
yellowness "b*"	Duroc	mean	4.36	5.04	4.87
		SD	1.94	2.26	2.50
	Pietrain	mean	6.30	6.29	6.13
		SD	1.22	0.99	1.12

bred for improved muscling, a beneficial effect on meat quality traits is exerted by the allele of the lowest frequency. Of course, this statement concerns mainly frequency of the *GPI locus* alleles [Kurył *et al*. 1996, Orzechowska *et al*. 2003] and the *PGD locus* alleles.

It should be asked how to conduct breeding and selection work in particular breeds to obtain animals with both high muscling and valuable meat. The research results would justify breeding work aimed at increasing frequency of the GPI^{A} allele, especially in Pietrain pigs. This could positively affect some indicators of meat quality. However, considering such a low frequency of animals with the $GPI^{A/B}$, and especially the $GPI^{A/A}$ genotype (about 2.5%, Tab. 1), this goal may be difficult to achieve.

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Zależności między genotypami w *locus GPI* i *PGD* a wybranymi cechami jakości mięsa świń ras duroc i pietrain

S t r e s z c z e n i e

Celem pracy było zbadanie wpływu poszczególnych alleli w *locus GPI* i *PGD* na cechy jakości mięsa świń.Materiał do badań stanowiły loszki rasy duroc i pietrain oceniane w stacjach SKURTCh w Mełnie i Pawłowicach w latach 2000-2002. Łącznie w badaniach uwzględniono 220 zwierząt, w tym 99 rasy duroc i 121 rasy pietrain. Zwierzęta utrzymywano, żywiono i ubijano zgodnie z obowiązującą metodyką oceny w stacjach kontroli SKURTCh. Analizą objęto następujące cechy jakości mięsa: pH mierzone 45 minut i 24 godziny po uboju (odpowiednio pH_{45} i pH_{24}), barwę mięsa we współrzędnych L, a, i b, oraz wodochłonność (WHC).

Przedstawione wyniki analizy statystycznej nie wskazują w sposób jednoznaczny, który z alleli *locus GPI* może znacząco wpływać na cechy charakteryzujące jakość mięsa. Niemniej jednak, wyższe wartości pH_{45} mięsa obserwowano u zwierząt z genotypem $GPI^{B/B}$ zarówno w rasie duroc, jak i pietrain. Z punktu widzenia pH_{24} mięsa genotyp $GPI^{A/B}$ okazał się korzystniejszy, jednak istotności jego wpływu genotypu na tę cechę nie udowodniono. Korzystny wpływ na cechy związane z barwą mięsa obserwowano u zwierząt rasy pietrain, które posiadały w swoim genotypie allel GPI^{A}. Mięso zwierząt o genotypie $GPI^{A/B}$ charakteryzowało się mniejszą jasnością (L), większym nasyceniem barwy czerwonej oraz mniejszą intensywnością barwy żółtej. Ponadto procent wody wolnej (WHC) był niższy w mięsie zwierząt, które w swym genotypie posiadały allel GPI^{A} i to zarówno w rasie pietrain, jak i duroc.

Wyniki analizy statystycznej dotyczącej cech jakości mięsa dla *locus PGD* wykazały nieznaczną różnicę w pH_{45} mięsa zwierząt rasy duroc. Najkorzystniejsze rezultaty odnośnie do tej cechy stwierdzono u zwierząt o genotypie $PGD^{B/B}$. W przypadku pozostałych cech nie obserwowano różnic między genotypami w *locus PGD*. Można zatem twierdzić, że gen *PGD* nie wpływa na cechy jakości mięsa świń.