The effect of DanAvl Duroc and Pulawska boars in crossbred with DanAvl Hybrid on meat quality of finishing pigs

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The research was aimed at determining the physicochemical and sensory properties of the *m. longissimus lumborum* at DanAvl Hybrid (Landrace – Yorkshire) fatteners and derived from DanAvl Hybrid sows and DanAvl Duroc and Pulawska boars. Fatteners derived from DanAvl Duroc boars were characterized by better meat quality compared to DanAvl Hybrids and their hybrids with Pulawska breed as evidenced by higher pH in 24–96 h *post mortem* (p.m.), higher sensory evaluation of juiciness, tenderness and flavor as well as lower shear force at lower content of total protein and higher content of intramuscular fat (IMF). However, DanAvl Hybrid fatteners were characterized by poorer meat quality, i.e. higher color lightness (L*) and higher drip loss both from fresh and thawed meat compared to those derived from DanAvl Duroc and Pulawska boars. Meat of fatteners after Pulawska breed was characterized by the highest redness (a*), and that after DanAvl Duroc breed, the lowest yellowness (b*) and saturation (C*).

Key words: crossbreeding, Danish and Polish breeds, pork

Introduction

In the DanAvl cross-breeding program (DanBred International), Danish Yorkshire (Y) and Danish Landrace (L) breeds are used, which are perfect for the production of gilts. DanAvl Hybrid results from the first cross-breeding of maternal line (LY/YL). Studies have shown that DanAvl Hybrid gilts have high fertility and prolificacy, give birth to 1.5 piglets per litter more than pure DanAvl Landrace and Yorkshire breeds, as well as have good maternal instinct (Kasprzyk and Łucki 2014). Duroc is a cross-breeding reproducer that has very good mating abilities (Chang et al. 2017). Research conducted by Danish National Committee for Pig Production, when comparing different breed combinations, has shown that pure DanAvl Duroc breed provides the best economic effects (Nielsen et al. 2013). The use of Duroc breed as a paternal component in cross-breeding in many pork production programs is justified by their high resistance to stress and thus good meat quality, which also results from the fact that pigs of this breed are characterized by IMF content, which is known to positively affect, among others, the sensory values of pork and lower shear force (Koćwin-Podsiadła et al. 2004a, Krzęcio et al. 2004, Grześ et al. 2005, Juárez et al. 2009). However, quality of carcass and meat of fatteners after pure-breed duroc boars may vary depending on which farm/program they come from (Cilla et al. 2006, Sieczkowska et al. 2010).

In Poland, in the production of high-quality pork, particular attention is paid to the breeds of domestic pigs, i.e. Pulawska, Zlotnicka White and Zlotnicka Spotted. These breeds have been subjected to intensive breeding for years, therefore, it has allowed maintaining high quality values, including darker, more desirable color of meat, specific taste and suitability for production of long-lasting cured meat. Research shows that meat of these pigs often shows an advantage in terms of quality traits in relation to that obtained from pigs of other breeds subjected to intensive breeding (Babicz et al. 2013, Szulc and Skrzypczak 2015, Wojtysiak et al. 2016, Cebulska et al. 2018, Debrecéni et al. 2018). Previous research indicates the beneficial impact of Pulawska breed in cross-breeding with Polish Large White (PLW) and Polish Landrace (PL) (Florowski et al. 2008) and Duroc (Babicz et al. 2009) on technological and sensory meat quality of fatteners. However, there are no studies, in which the possibility of using the native Polish Pulawska breed for cross-breeding with Danish breeds in the production of high-quality meat would be analyzed. Concerning the above, it can be assumed that using both Duroc and Pulawska boars crossbred with fertile and prolific DanAvl Hybrid sows allows for obtaining meat that is technologically and culinary of high quality.

The aim of the research was to determine physicochemical and sensory properties of *longissimus lumborum* muscle of hybrid fatteners derived from Landrace and Yorkshire (DanAvl Hybrid) breeds and their hybrids after purebred DanAvl Duroc and Pulawska boars.

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Material and methods

Animals

The research was carried out in the summer season using three groups of crossbred fatteners, that came from one company dealing with the production of pigs in the Pomeranian Voivodeship (Poland). The study involved DanAvl Hybrid fatteners and fatteners derived from the offspring of DanAvl Hybrid sows, (Landrace – Yorkshire; LY) the pure-bred boars DanAvl Duroc from DanBred International and the pure-bred boars Pulawska which were housed under the same environmental conditions with a non-bedding system (on grates). All pigs received drinking water and the same complete feed mixture for fatteners *ad libitum* system.

At a defined week, each group of 50 LY sows were inseminated by the selected boars, i.e.: DanAvl Duroc (5); Pulawska (3); Yorkshire/Landrace (3). The Pulawska boars' semen came from the farm which fulfill Pulawska Breed Genetic Resources Protection Program requirements (zamojski district, lubelskie voivodeship, Poland). According the performance testing, Pulawska boars reached the growth in fattening period of 625 g/day and meatiness of pig carcasses – 55.4%.

After reaching a body weight of about 112 kg, fatteners from a given group (in the number of 60), non-mixing of unfamiliar pigs, were all transported to Meat Plants (Table 1). All three groups of fattening pigs were transported by the same means of transport, at which the temperature was in the range of 22 – 24 °C. After unloading, the pigs were given to 15 hours of pre-slaughter rest at an ambient temperature of 16 – 18 °C; the duration of fasting time before slaughter was 24 hours.

Table 1. Experiment layout

Numbers	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
Fatteners	60	60	60
Carcasses	30	28	30
Gilts/Barrows	12/18	14/14	15/15

Carcass and meat quality

On the slaughter line, after the pigs were stunned (Butina CO_2 gas stunning system, Denmark), lean meat percentage in the carcass, was non-invasively ultrasonically measured (AutoFom, SFK Technology, Denmark) and sex of fatteners was determined. Before cooling, the hot carcass weight was determined with an accuracy of 100 g. Next, the carcasses were progressively chilled for 24 h. At first, they were cooled at a temperature of +1 °C for 7 – 8 h, and then after filling the store, the carcasses were cooled at a temperature between –3 °C and –4 °C for 6 − 7 h, and then at 4 − 6 °C for the rest of the time (about 10 h). In a cold store, based on the identified sex and a defined hot carcass weight, 30 carcasses of similar weight (90 ± 5 kg) and similar share of gilts and barrows were selected from each group.

After cooling the carcasses, during cutting the right halves into the basic elements, the *m. longissimus lumborum* (LL) samples were taken for testing. The LL muscle samples, packaged in labeled foil pouches, were transported in thermoses to the laboratory and stored in a refrigerator at 4 °C. Then, 3 slices 3 cm thick were cut out of the muscle samples starting from the head section, to determine the drip loss, pH and color characteristics. The remainder of the muscle was packed into labeled plastic bags and frozen at –19 °C for approximately one month to determine water binding, shear force and sensory evaluation.

The following qualitative determinations were made on fresh LL muscle:

The pH was measured 35 min, 3 h and 24 h (in a cold room, right halves), 48 h and 96 h *p.m.* using portable pH-meter equipped with a temperature sensor (CP-411 pH-meter, Elmetron, Poland).

Electrical conductivity was determined at 2 and 24 h *p.m.* (EC_2 and EC_{24}) in a cold room on the right halves using the LF-Star device (Ingenieurbüro Matthäus, Germany).

Drip loss was determined by the method of Prange et al. (1977). In 24 h *p.m.*, muscle samples weighing 50 g (cut out from the middle part of the 3 cm thick slice) were put in plastic bags and stored at 4 °C. Drip loss was defined as % loss in mass after 1 day (48 h *p.m.*) and 3 days (96 h *p.m.*) of storage.

The measurement of color features was performed on freshly cut muscle slices 24 and 48 h *p.m.*, after 20 min blooming period at 4 °C, by determining the lightness (L*), redness (a*), yellowness (b*), chroma (C*) and hue (h^0), by means of a HunterLab Mini Scan XE Plus 45/0 (HunterLab Inc., Virginia, U.S.) with a standard illuminant D65 and 10° Standard Observer.

Water losses during thawing and cooking

A fragment of LL muscle (about 300 g) was removed from the freezer, weighed (pre-thaw weight), thawed at 4 °C for about 24 h and re-weighed (pre-cook weight). The sample were heated in water at 80 − 81 °C in an oven until reaching an internal temperature of 72 °C inside the meat samples and were then subjected to shear force and sensory evaluation after cooling to 20 °C and weighted (post-cook weight).

Shear force and sensory evaluation

Shear force was measured using a Warner-Bratzler apparatus (WB) manufactured at the Baking Industry Research Centre (Bydgoszcz, Poland). Cylinder-shaped meat samples cut out with a cork borer with a diameter of 1.0 cm (along the muscle fibers) were placed in a triangular recess under the five blades of the tenderness measuring instrument, which then recorded the maximum force (expressed in kilograms) required for cutting through the meat. The final result for each sample was the average of three consecutive trials.

Sensory evaluation of the LL samples was performed to determine their color, aroma, tenderness, juiciness and flavor. Samples had approximately equal sizes (about 25 g) and were placed in lidded one ounce glass jars labeled with three digit random codes and held in a water bath (54 °C) until presented to the panelists. The analysis was conducted in rooms at daylight and at a room temperature (20 °C). To neutralize the taste, each person received hot tea without sugar between the assessments of samples. This evaluation was performed in 9 sessions by a team of 5 trained individuals using a 5-point scale (1 = unacceptable and 5 = very acceptable) according to ISO 4121:2003 and ISO 8586:2012. During the two sessions that took place each day, all panelists received, at the same time, 10 coded samples.

Proximate analysis

The basic chemical composition of LL muscles was determined in accordance with the official analytical methods of the AOAC (2006): moisture content by the oven-drying of 2 g samples at 102 °C to a constant weight (950.46B, see p.39.1.02); crude protein content by the classical macro-Kjeldahl method (992.15, see p.39.1.16) and intramuscular fat content by petroleum ether extraction using a Soxhlet apparatus (960.39 (a), see p.39.1.05). The total mineral (ash) content was determined by incineration at 550 °C (923.03, see p.32.1.05).

Polymorphism of the *RYR1* gene

Genomic DNA was extracted from muscle samples using GeneMATRIX Tissue DNA Purification Kit (EURx, Poland). The *RYR1* polymorphism was analyzed by polymerase chain reaction-restriction fragment length polymorphism method (PCR-RFLP) using following primer sequences: RYR1_F 5'-TCCAGTTTGCCACAGGTCCTACCA-3'; RYR1_R-5'-ATTCACCGGAGTGGAGTCTCTGAG-3' (Ruan et al. 2013). Identification of the stress sensitivity gene (*RYR1*) revealed the occurrence of individuals with heterozygous genotype (*CT*) only in the group of fatteners derived from Pulawska breed boars (n = 2). In the remaining groups, all fatteners were free from the *T* allele at the *RYR1* locus. Therefore, we removed individuals with *CT/RYR1* genotype from further analysis, which allowed for analyzing the quality traits of the carcass and meat only at fatteners with genotype *CC/RYR1*.

Statistical analysis

The obtained data was analysed statistically (Statistica 13.1 PL), using the least squares method of the GLM procedure according to the following linear model:

$$Y_{ijk} = \mu + a_i + b_j + \beta(x_{ijk} - \bar{x}) + e_{ijk}$$

where: Y_{ijk} – trait measured; μ – the overall mean; a_i – the effect of breed (i = 1, 2, 3); b_j – the effect of sex (j = 1, 2); β - linear regression coefficient for hot carcass weight; x_{ijk} - hot carcass weight of ijk-th individual included as covariable; e_{ijk} – the random error.

The detailed comparison of mean least squares (LSQ) for the analysed breed was done using a Tukey's test. The tables show LSQ and their standard errors. In the statistical analysis, the relationship between fattening pigs (full sibs and half sibs) was not taken into account.

Results

Production results and chemical composition of meat

On the grounds of the information from the farm, the fattening time of DanAvl Hybrid fatteners and their crossbreed with Duroc breed was similar and came to 79 days (age 159 days). During the period, the average weight gain was about 1075 g. The fattening of crossbred LY sows with Pulawska boars was longer and lasted 99 days (age 179 days). The average weight gain was about 850 g during this period.

In the statistical model adopted for the analysis, we took into account the influence of the hot carcass weight as we found significant differences between analyzed groups of fatteners in this respect (Table 2).

Table 2. Carcass quality and basic chemical composition

Traits	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
Hot carcass weight (kg)	$88.40^{B} \pm 3.16$	$90.53^{A} \pm 1.68$	$88.03^{B} \pm 1.41$
Meatiness (%)	$57.91^{ab} \pm 1.58$	$58.29^{a} \pm 2.75$	$57.10^{b} \pm 1.96$
Total protein (%)	$21.62^{B} \pm 0.55$	$22.09^{A} \pm 0.42$	$20.96^{C} \pm 0.50$
Intramuscular fat (%)	$1.73^{B} \pm 0.85$	$1.53^{B} \pm 0.55$	$2.57^{A} \pm 0.71$
Dry matter (%)	25.34 ± 0.75	25.64 ± 0.40	25.53 ± 0.84
Ash (%)	1.16 ± 0.05	1.18 ± 0.03	1.18 ± 0.09

^{A,B} Mean values marked by different large letters differ significantly at $p \leq 0.01$; ^{a,b} Mean values marked by different small letters differ significantly at $p \leq 0.05$.

Based on the result analysis, we showed that fatteners after pure-breed DanAvl Duroc boars were characterized by significantly lower carcass meatiness in comparison to those after Pulawska boars (57.1% vs. 58.29%), and hybrids of Yorkshire with Landrace (DanAvl Hybrid) – the intermediate meatiness between these groups of fatteners. Analysis of basic chemical composition showed that the LL muscles of fatteners after DanAvl Duroc boars were characterized by significantly higher IMF content and lower total protein in relation to DanAvl Hybrids fatteners and their hybrids with Pulawska breed.

Pork quality characteristics

The study has shown that chilled carcasses of fatteners after DanAvl Duroc boars were characterized by significantly higher pH of LL muscle on various *p.m.* dates (pH_{24}, pH_{48}, pH_{96}) compared to DanAvl Hybrid and their hybrids with Pulawska breed (Table 3). Also, fatteners derived from DanAvl Duroc boars had better meat quality based on lower thaw loss and total fluid losses relative to DanAvl Hybrid pigs (Table 4).

Table 3. pH and electrical conductivity (EC)

Traits	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
pH_{35min}	6.61 ± 0.24	6.59 ± 0.21	6.58 ± 0.15
pH_3	6.07 ± 0.19	6.01 ± 0.25	5.91 ± 0.19
pH_{24}	$5.51^{B} \pm 0.05$	$5.50^{B} \pm 0.08$	$5.65^{A} \pm 0.16$
pH_{48}	$5.48^{B} \pm 0.06$	$5.50^{B} \pm 0.09$	$5.72^{A} \pm 0.20$
pH_{96}	$5.56^{B} \pm 0.05$	$5.51^{B} \pm 0.07$	$5.68^{A} \pm 0.14$
EC_2 (mS cm^{-1})	3.49 ± 0.78	3.37 ± 0.90	3.49 ± 1.03
EC_{24} (mS cm^{-1})	4.17 ± 1.08	4.44 ± 1.68	3.94 ± 1.18

^{A,B} Mean values marked by different large letters differ significantly at $p \leq 0.01$.

Table 4. Water loss measurements on fresh and frozen muscle

Traits	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
fresh meat			
drip loss$_{24}$ (%)	$3.54^{A} \pm 0.83$	$2.27^{B} \pm 0.85$	$2.19^{B} \pm 0.99$
drip loss$_{72}$ (%)	$6.34^{A} \pm 1.24$	$4.94^{B} \pm 1.58$	$4.37^{B} \pm 1.75$
frozen meat			
Thawed loss (%)	$11.26^{A} \pm 4.12$	$9.66^{AB} \pm 3.14$	$7.72^{B} \pm 3.49$
Cooked loss (%)	28.67 ± 3.90	28.19 ± 2.65	27.75 ± 3.38
Total fluid loss (%)	$36.80^{A} \pm 2.83$	$35.16^{AB} \pm 2.62$	$33.28^{B} \pm 4.77$

^{A,B} Mean values marked by different large letters differ significantly at $p \leq 0.01$

In addition, fatteners after DanAvl Duroc and Pulawska boars were characterized by better quality of meat as compared to DanAvl Hybrid pigs, as evidenced by significantly lower drip loss determined after 24 and 72 hrs of refrigeration storage and lower lightness (L*) determined at both 24 and 48 hrs *p.m.* (Table 5).

Table 5. Colour traits

Traits	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
24 h post mortem			
L*	$58.65^{A} \pm 2.06$	$56.06^{B} \pm 1.89$	$55.24^{B} \pm 2.78$
a*	$4.46^{Bb} \pm 1.02$	$5.40^{A} \pm 0.70$	$5.10^{a} \pm 1.06$
b*	13.53 ± 1.76	13.76 ± 0.55	13.34 ± 0.60
C*	$14.60^{ab} \pm 0.85$	$14.80^{a} \pm 0.60$	$14.32^{b} \pm 0.61$
h^{0}	70.17 ± 12.34	68.58 ± 2.55	69.13 ± 4.21
48 h post mortem			
L*	$58.43^{A} \pm 2.86$	$55.28^{B} \pm 1.87$	$56.36^{B} \pm 2.88$
a*	$5.37^{B} \pm 1.00$	$6.53^{A} \pm 0.58$	$5.47^{B} \pm 0.82$
b*	$14.36^{A} \pm 0.67$	$14.37^{A} \pm 0.69$	$13.66^{B} \pm 0.57$
C*	$15.36^{Ab} \pm 0.82$	$15.79^{Aa} \pm 0.67$	$14.74^{B} \pm 0.53$
h^{0}	$69.59^{A} \pm 3.24$	$65.54^{B} \pm 2.19$	$68.21^{A} \pm 3.29$

^{A,B} Mean values marked by different large letters differ significantly at $p \leq 0.01$; ^{a,b} Mean values marked by different small letters differ significantly at $p \leq 0.05$

Analysis of color chromatic features 24 hrs *p.m.* showed at Pulawska fatteners significantly higher redness (a*) of the LL muscle compared to DanAvl Hybrid pigs and significantly higher color saturation (C*) compared to DanAvl Duroc breed. Also 48 hrs after slaughter, the LL muscle of fatteners after Pulawska breed had significantly higher redness (a*) compared to other groups of hybrid fatteners. In addition, lower yellowness (b*) and saturation (C*) of the LL muscle were found in fatteners after DanAvl Duroc boars with reference to DanAvl Hybrids and their hybrids with Pulawska breed.

Sensory characteristics and shear force

Sensory analysis of LL muscles subjected to thermal treatment showed significantly higher assessment of distinguishing factors, i.e. juiciness, flavor and tenderness at fatteners after pure-breed DanAvl Duroc boars as compared to other analyzed groups of hybrid fatteners, which was also confirmed in instrumental measurement of the shear force (Table 6). In contrast, LL muscles of pigs derived from DanAvl Duroc boars had lower color rating compared to DanAvl Hybrid fatteners and lower aroma rating than DanAvl Hybrids and their hybrids with Pulawska breed.

Table 6. Sensory assessment and shear force

Traits	Group of pigs		
	DanAvl Hybrid (LY)	Pulawska × LY	DanAvl Duroc × LY
Colour (pts)	$4.84^{a} \pm 0.13$	$4.76^{ab} \pm 0.25$	$4.69^{b} \pm 0.21$
Aroma (pts)	$4.97^{A} \pm 0.06$	$4.98^{A} \pm 0.05$	$4.70^{B} \pm 0.16$
Tenderness (pts)	$3.63^{B} \pm 0.52$	$3.68^{B} \pm 0.59$	4.13A ± 0.55
Juiciness (pts)	$3.42^{b} \pm 0.49$	$3.34^{B} \pm 0.64$	$3.82^{Aa} \pm 0.54$
Flavour (pts)	$3.51^{B} \pm 0.43$	$3.62^{B} \pm 0.61$	$4.07^{A} \pm 0.42$
Shear force (kg)	$5.14^{A} \pm 0.76$	$4.52^{Ba} \pm 0.52$	$4.09^{Bb} \pm 0.69$

^{A,B} Mean values marked by different large letters differ significantly at $p \leq 0.01$; ^{a,b} Mean values marked by different small letters differ significantly at $p \leq 0.05$

Discussion

Lean content and chemical composition of meat

In our studies, hybrids derived from DanAvl Hybrid sows and DanAvl Duroc boars obtained a meatiness close to 58% with a carcass weight of 88.4 kg. Similar carcass meatiness (58.86%) of 4433 animals imported from Denmark hybrid pigs – (LY) × Duroc (D) was found in studies by Bojko and Rekiel (2014). In these studies, it was also shown that participation of carcasses in classes S and E was 92.9% in total at 94.24 kg mean weight of carcass in classes. According to the authors mentioned, the obtained results indicate very good, and first of all, repeatable quality of the examined hybrid fatteners in respect of traits that are economically important for meat producers and meat industry. In other studies (Koćwin-Podsiadła et al. 2004b) using material also from Denmark, similar carcass meatiness was found for LY fatteners and their hybrids with Duroc breed and pure-bred fatteners Landrace (from 56.14% to 56.91%). Moreover, crossbreeds (LY) × D in comparison to maternal group LY had thicker backfat, heavier loin without fat and skin, heavier shoulder and lightest both belly and ham without fat and skin. Cilla et al. (2006) analyzed the quality of carcass and meat of fatteners after Landrace × Large White sows and pure-bred Duroc boars from three breeding programs. They found that fatteners derived from Duroc from DanBred boars were characterized by better muscularity and lower fat content at similar weight as compared to Duroc boars from other programs. In contrast, Sieczkowska et al. (2010) showed similar meatiness and weight of fattener's carcass after LY sows and pure-bred Duroc boars originated from Danish and Polish pedigree breeding.

In our research, we found the highest IMF content and at the same time the lowest total protein in LL muscle of fatteners after DanAvl Duroc boars. Studies by Koćwin-Podsiadła et al. (2004a) and Grześ et al. (2005) involving material from Denmark, indicate significant effect of pure-bred Duroc boars in crossbreeding with LY sows on the increase in IMF content. In addition, similar IMF content as in our studies for hybrids after Duroc from DanBred boars was obtained by Cilla et al. (2006). Also, the content of total protein and IMF in LL muscle for LY hybrids, similar to our results, was obtained in studies by Koćwin-Podsiadła et al. (2004a), Grześ et al. (2005) and Zhang et al. (2018).

In this study, hybrids after DanAvl Hybrid sows and Pulawska boars were characterized by high carcass meatiness (over 58%) at carcass weighing around 90 kg. In other studies, there was a lower carcass meatiness of fatteners after pure-bred Pulawska boars in relation to their hybrids with PLW (Florowski et al. 2008) and PL breed sows (Borzuta et al. 2006, Florowski et al. 2008). This is in line with results of studies showing lower meatiness of pure-bred Pulawska fatteners in relation to pure-bred PL breed ones (Piórkowska et al. 2010, Kasprzyk et al. 2013) as well as PLW, Pietrain and Duroc (Piórkowska et al. 2010). Moreover, in the studies by Babicz et al. (2009) using fatteners slaughtered at a body weight of 135 – 140 kg, it was shown that cross-breeding of Duroc with Pulawska breed caused an increase in backfat thickness and revealed relatively high gains of ham and loin in relation to total valuable cuts.

In our research, fatteners after DanAvl Hybrid sows and Pulawska boars were characterized by fairly low IMF content and, at the same time, the highest total protein content among the analyzed groups of hybrid fatteners. In other studies, slightly higher IMF content in *m. longissimus* was found in hybrids after Pulawska sows and PL (1.9%) and PLW (2.3%) boars (Florowski et al. 2007) and remarkably higher with Duroc boars (3.05%) (Babicz et al. 2009). For comparison, the content of IMF in *m. longissimus* was similar for pure-bred fatteners of Pulawska (2.2%), PL (1.98%) and PLW breed (2.10%) (Piórkowska et al. 2010). In other studies, fatteners of Pulawska breed had significantly higher IMF content (3.70%) in *m. longissimus* (Florowski et al. 2007) and 2.98% in *m. semimembranosus* (Wojtysiak et al. 2016).

Pork quality characteristics

In our studies, fatteners after DanAvl Duroc boars had higher pH (24 – 96 hrs *p.m.*), lower losses from fresh and thawed meat as well as lower lightness (L*) of LL muscle as compared to DanAvl Hybrid fatteners. Also in other studies upon material originating from Denmark, the beneficial effect of crossbreeding the LY sows with pure-bred duroc boars with respect to LY and pure-bred Landrace fatteners had been demonstrated on the physicochemical properties and technological value of meat, as evidenced by lower rate and range of pH fall, 1.5 – 2.0 pp lower drip loss and by 1.5 pp higher technological yield in cooking and curing process expressed by technological yield (Koćwin-Podsiadła et al. 2004a). Different research results are presented by Zhang et al. (2018), in which the authors found higher pH 45 min and lower drip loss of *m. longissimus* in LY fatteners as compared to LY × D. In studies performed by Sieczkowska et al. (2010), more favorable quality of meat was found at fatteners after LY sows and Duroc boars from Danish pedigree breeding than from Polish breeding at similar IMF content and glycolytic resource of LL muscle in 45 min *p.m.*. In contrast, Cilla et al. (2006) found similar pH (45 min and 24 hrs *p.m.*) in fatteners derived from duroc boars coming from three breeding programs, however a slightly higher electrical conductivity and lightness (L*) of *m. longissimus thoracis* were found in more leaner hybrids after Duroc boars from DanBred.

In the present study, Pulawska breed was beneficial in crossbreeding with DanAvl Hybrid in respect to the quality of meat as well as reducing the drip loss and darker color (L*) of LL muscle. In study carried out by Wojtysiak et al. (2016), lower drip loss, shear force and L* values were observed in Pulawska pigs as compared to Pietrain and PLW breeds. These studies have also revealed that muscles of Pulawska pigs are the most oxidative (type I and IIA fibers), but muscles of Pietrain pigs are the most glycolytic ones (type IIB fibers). Ryu and Kim (2005) observed positive relationship between percentage of type IIB fibers and L*, drip loss of *m. longissimus dorsi*. However, research by Florowski et al. (2008) indicate poorer quality of pure-bred Pulawska pigs compared to their hybrids with PLW and PL breeds as evidenced by lower pH (45 min, 24 hrs *p.m.*) as well as water holding capacity and higher lightness (L*). Poorer quality of Pulawska pigs meat found in these studies may be related to the aforementioned high frequency of *T*-allele of *RYR1* gene in this breed, which is known to be responsible for the formation of poor meat quality - PSE (pale, soft, exudative).

In our research, on the basis of chromatic analysis of color, it was found that the LL muscles of fatteners after Pulawska breed had the highest redness (a*), while pigs after DanAvl Duroc boars had the lowest yellowness (b*) and saturation (C*). In the studies of Wotysiak et al. (2016), higher a* values in *m. semimembranosus* were found in Pulawska pigs in relation to Pietrain and PLW breeds. In studies by Zhang et al. (2018), significantly higher a* and b* values were found in the LY × D fatteners as compared to LY pigs. The lowest b* for LL muscle at fatteners after DanAvl Duroc found in our study is probably related to the highest pH 24 – 96 hrs *p.m.* in this group, better water-holding capacity and lower shear force as compared to LY pigs. As indicated by Ryu and Kim (2005), crossbred LY × D, yellowness (b*) significantly negatively correlates with pH (45 min and 24 hrs *p.m.*) and significantly positively with drip loss and filter-paper fluid uptake (FFU) as well as shear force. In these studies, however, there were no significant relationships between redness (a*) and quality traits, except from positive correlation of a* with FFU. Karamucki et al. (2013) reported significant negative correlations between pH (48 hrs *p.m.*) and chromatic features of LL muscle (a*, b* and C*) as well as significant positive relationships between the mentioned color characteristics and IMF.

Sensory characteristics

The present research has shown the most beneficial sensory quality of tenderness, juiciness and flavor, and the lowest LL muscle cutting force in fatteners after DanAvl Duroc boars. Confirmation of the obtained results is the study by Grześ et al. (2005) involving pigs from Denmark, at which higher tenderness and juiciness values and lower shear force in the meat obtained from the LY × D crosses in relation to LY fatteners, were found. This is probably related to found both in our research and that of Koćwin-Podsiadła et al. (2004a) and Grześ et al. (2005) higher pH_{24} and water holding capacity, lower cooking losses and higher content of IMF for LY × D hybrids in relation to LY, LY × Pulawska, Landrace. Zhang et al. (2018) did not find differences between LY and LY × D hybrids in shear force, at significantly higher pH 45 min and lower drip loss at LY fatteners as well as higher IMF content and marbling at LY × D fatteners. Wojtysiak et al. (2016) have shown that IMF is associated with lower drip loss and shear force of *m. semimembranosus* at Pulawska, which is not confirmed by study of Florowski et al. (2007, 2008). They reported that pure-bred Pulawska fatteners were characterized by higher IMF content and worse physicochemical properties of meat as compared to hybrids of that breed with PLW and PL breeds at insignificant difference in shear force. As indicated by the results of Huff-Lonergan et al. (2002), in their research pH_{24} significantly negatively correlated with the drip loss (–0.33) and cooking loss (–0.20), and positively with tenderness (0.27) and juiciness (0.25). On

the other hand, drip loss and cooking loss significantly negatively correlated with tenderness scores (–0.28 and –0.30) and positively with shear force (0.29 and 0.34). Moreover, the meat of pig carcasses with a high content of IMF, a factor known to be responsible for lower incidence of pale, soft, exudative meat (PSE) (Jones et al. 1994), but primarily for the higher sensory quality of meat (Fortin et al. 2005). It has been reported that in pork optimum sensory properties are achieved at 2 – 3.5% IMF (Wood et al. 1999). In order to obtain the optimum fat content genetically, Duroc pigs may be recommended as one of the most suitable breeds. It has been reported that the fat content and meat quality of pork improves when pigs are at least 50% Duroc (Warris 2000, Juárez et al. 2009).

Conclusions

In qualitative studies upon three groups of fatteners with the genotype *CC/RYR1*, it was found that hybrid fatteners derived from DanAvl Duroc boars were characterized by the best quality of meat as evidenced by the highest pH determined in 24 – 96 hrs *p.m.*, the highest evaluation of sensory characteristics of cooked meat - juiciness, tenderness and flavor and the lowest shear force, which probably is related to the highest IMF content found in them. However, the worst quality of meat was found at DanAvl Hybrid fatteners in terms of lightness (L*) and drip loss from both fresh and thawed meat. The LL muscle of fatteners after Pulawska breed was characterized by the highest redness (a*), and fatteners after DanAvl Duroc breed - the lowest yellowness (b*) and color saturation (C*).

The presented results unambiguously indicate that pork sourced from all the crossbred groups of pigs was of high quality. All the analyzed crossbreeds contained a desirable amount of IMF, which exceeded 2% in *longissimus lumborum* muscles only for the crossbreeds with the DanAvl Duroc breed. The protein content in muscles was also high in all the groups; however, the highest protein contents were affirmed in the meat of fatteners sired by Pulawska boars. The pork from the crossbreeds with DanAvl Duroc and Pulawska boars was normal, with a reddish-pink color. The evaluation of meat acidification confirmed the appropriate process of meat maturation, which is typical for normal meat. To sum up, the obtained results indicate that both DanAvl Duroc and Pulawska boars may be used for crossbreeding with DanAvl Hybrid sows when it comes to the production of high quality meat.

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