Bulgarian Journal of Agricultural Science, 26 (No 6) 2020, 1292–1296

Quality of meat in purebred pigs involved in crossbreeding schemes. II. Fatty acid composition of *m. Longissimus thoracis*

Teodora Popova[1*], Jivko Nakev[2], Jose Manuel Lorenzo Rodriguez[3]

[1]*Institute of Animal Science, Kostinbrod 2232, Bulgaria*
[2]*Agricultural Institute, Shumen 9700, Bulgaria*
[3]*Centro Tecnológico de la Carne de Galicia, Ourense 32900, Spain*
[*]*Corresponding author:* tlpopova@yahoo.com

Abstract

Popova, T., Nakev, J., & Rodriguez, J. M. L. (2020). Quality of meat in purebred pigs involved in crossbreeding schemes. II. Fatty acid composition of m. Longissimus thoracis. *Bulg. J. Agric. Sci., 26 (6)*, 1292–1296

The study was aiming to compare the fatty acid composition of *m. Longissimus thoracis* (*m. LT)* in four pig breeds – Landrace, Pietrain, Large White and Duroc, as well as some related indices characterizing the nutritional quality of the meat. The differences in the examined traits were assessed by one way ANOVA. Duroc pigs displayed the highest content of C14:0 and C18:1n-9 in *m. LT*, while the levels of these fatty acids were the lowest in Pietrain and Large White, which was accompanied also by the lowest levels of intramuscular lipids in these two breeds. Furthermore, the content of C18:0 was higher in Large White and Landrace, when compared to Duroc and Pietrain. Despite the highest amounts of C18:1n-9 and respectively the total monounsaturated fatty acids (MUFA) in *m. LT* of Duroc pigs, the animals of this breed displayed the lowest contents of both individual and total polyunsaturated fatty acids (PUFA). This was visible especially in comparison with the fatty acid profile of the Large White pigs exhibiting the higher contents of PUFA in the *Longissimus* muscle. The ratio n-6/n-3 had the highest values in the meat of Landrace pigs, while the lowest in Duroc, however, in regard to the ratio between polyunsaturated and saturated fatty acids (P/S), the most favorable values were found in Pietrain and Large White pigs. The lipid content was strongly related with the fatty acid profile of the muscle showing highly significant positive correlation with the MUFA content ($r = 0.735$, $P < 0.001$) and negative ($r = -0.734$, $P < 0.001$) with the PUFA.

Keywords: pork; breed; fatty acids; total lipids

Introduction

The global meat production and consumption have increased rapidly in recent decades, with pork being the most widely eaten meat world-wide, as its consumption reached 15.3 kg per capita in 2015 (The Satistical Portal, 2015). As a good source of protein, vitamins and minerals, meat can become a part of a healthy and balanced diet. It is well known, however, that the nutritive value of meat depends strongly on the fat content and fatty acid composition of the muscles, as both factors can strongly influence the human health (Calder, 2015). Some meats contain high amounts of SFA, which can have detrimental effect on the plasma lipids through increase of the low density lipoproteins (Fernandez & West, 2005) and hence reduce the healthy value of meat. According to Wood et al. (2004), lean pork contains a fairly constant proportion of cell membrane phospholipids, which are relatively rich in PUFA, while the content of the neutral lipids, composed mainly of SFA-rich triacyglycerols varies considerably. The increase of the PUFA and hence improvement of the fatty acid composition of pork can be achieved by reducing its total fat content. In response, selection in pig industry in many countries was directed to increase the lean meat percent in the carcass. The result of this process was dramatic decrease in the intramuscular fat but also negative effect on the sensory quality (Cannata et al., 2009). Cameron and Enser (1991) investigated the relationship between the fatty acid profile of the intramuscular fat and the composition of pork showing that the correlations among the concentration of specific fatty acids and eating quality traits were generally weak. However, they found that the correlations among PUFA and palatability scores were generally negative while those for SFA and palatability scores were generally positive, suggesting that the higher degree of unsaturation of the adipose tissue is associated with greater incidence of abnormal flavors (Burkett, 2009). Pigs are monogastric animals and the fatty acid composition of their tissues reflects the lipid profile of their diet and could be manipulated through various supplements. On the other hand, apart from the diet, the fatty acid profile differs between the pig breeds, and this could be explained with their different abilities for adipose deposition (Wood et al., 2004). The knowledge about these differences could allow to use the most suitable breeds in crossbreeding process for pork production in order to influence considerably the deposited fat and at the same time to manipulate the fatty acid profile to meet the consumers demands for healthy and tasty meat. In the present study we used four breeds – Landrace, Pietrain, Large White and Duroc which are often involved in the crossbreeding schemes for pork production and compared them in regard to the fatty acid profile of *m. Longissimus thoracis*.

Material and Methods

The study was carried out in the pig farm Golyamo Vranovo Invest AD with a total of 24 gilts divided into four groups according the breed: Landrace (n=6), Pietrain (n=6), Duroc (n=6) and Large White (n=6). During the finishing period the animals were reared according to the instructions described in the Regulation 21/14.12.2005 concerning the minimum requirements for protection and welfare for pig breeding when the animals are provided feed and water *ad libitum*. Two phase feeding was applied, as the first phase was in the period 40-80 kg, while the second phase was from 80 kg until slaughter. The diet composition is presented in Table 1. After slaughtering, the pigs were skinned. The carcass weight was as follows: Landrace – 83.39 kg (SEM 0.55), Pietrain 84.06 (SEM 0.89), Duroc 84.06 (SEM 0.89) and Large White 84.84 (SEM 0.76). Samples for analysis of the fatty acid composition were taken from *m. LT* at the last rib of the left side of each carcass. The samples were minced with a meat grinder, and samples for the determination of the fatty acid profile (10 g) were taken, vacuum-packed and stored at -20°C until analysis. Total lipids from *m. LT* were extracted according to the method of Bligh and Dyer (1959). Methyl esters of the total lipids, isolated by preparative thin layer chromatography, were obtained using 0.01% solution of sulfuric acid in dry methanol for 14 h, as described by Christie (1973). The fatty acid composition of the total lipids was determined by gas-liquid chromatography (GLC) analysis using a chromatograph C Si 200 equipped with a capillary column (DM-2330:30 m×0.25 mm×0.20 μm) and hydrogen as a carrier gas. The oven temperature was first at to 160°C for 0.2 min, then raised until 220°C at a rate of 5°C/min and then held for 5 min. The temperatures of the detector and injector were 230°C. Methyl esters were identified through comparison to the retention times of the standards. Fatty acids are presented as percentages of the total amount of the methyl esters (FAME) identified (Christie, 1973).

The data were statistically evaluated through one way ANOVA and Tukey post hoc comparisons. To assess the relationships between intramuscular lipid and the fatty acid composition with related lipid nutritional indices, Pearson correlation coefficients were calculated. The statistical procedures were performed using the JMP v. 7 software package.

Table 1. Diet composition

Components	Finisher I phase	Finisher II phase
Corn, %	21.00	18.00
Barley, %	23.30	23.40
Wheat , %	19.00	23.00
Soy meal , %	15.00	16.00
Sunflower expeller, %	18.00	16.00
Soy oil, %	2.40	2.40
Limestone, %	0.50	0.50
Panto Mix 3148 finisher, %	0.20	0.20
Hostazim + Optiphos, %	0.10	0.10
Lysine, %	0.20	0.20
Salt, %	0.30	0.20
Total	100.00	100.00
ME, kcal	3424	3432
Crude protein, %	19.052	18.89
Crude fibers, **%**	5.37	5.14
Fat, **%**	5.93	5.77
Lysine, %	1.07	1.08
Methyonine, %	0.34	0.33
Methyonine + Cysteine, %	0.65	0.64
Trpiptophane, g	0.31	0.30
Ca, **%**	0.48	0.48
P, **%**	0.60	0.59

Results and Discussion

As shown in Figure 1, the content of the total intramuscular lipids differed among the examined breeds (P < 0.001). Duroc pigs showed the highest levels (3.15%), when compared to the other breeds (P < 0.05), while the Large White tended to have the lowest intramuscular lipid content.

Significant differences between the breeds were found in regard to the content of the most of the fatty acids in *m. LT* (Table 2). The saturated fatty acids identified in this study were C14:0, C16:0 and C18:0. While no significant differences were found in the content of C16:0, the levels of the other two fatty acids differed considerably among the breeds. Similar to the content of total lipids, Duroc exhibited the highest amount of C14:0 (P < 0.05) when compared to Pietrain and Large White. The latter also tended to have the lowest content of C14:0 among the breeds. This pattern was however not observed in regard to the content of C18:0 of *m. LT*, where Duroc and Pietrain exhibited lower levels of this fatty acid when compared to Landrace and Large White (P < 0.05).

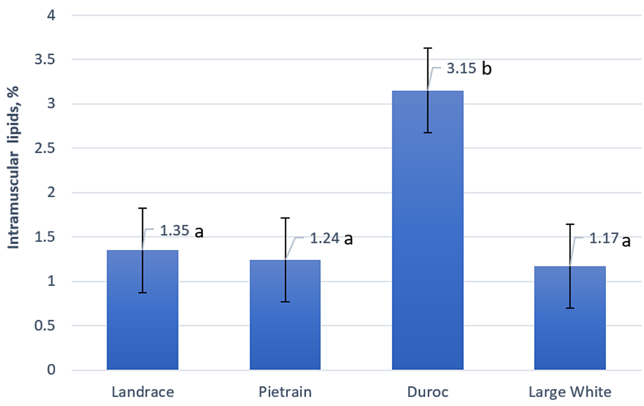

Fig. 1. Intramuscular lipid content in the studied breeds
Note: Means connected with different lettes differ significantly (P < 0.05)

The major monounsaturated fatty acids C18:1n-9 differed significantly among the breeds (P < 0.001) following the trend of C14:0. The results revealed that the highest content of C18:1n-9 was observed in the muscle of Duroc, while the lowest were found in Pietrain and Large White. The highest amounts of both C14:0 and C18:1n-9 corresponded to the highest levels of total intramuscular lipids in *m. LT* of Duroc measured in this study.

The content of the majority of the polyunsaturated fatty acids of *m. LT* showed considerable variation among the studied breeds. The Duroc gilts displayed the lowest amounts of C18:2n-6, C20:3n-6, C20:4n-6, C20:5n-3 and C22:5n-3, as the differences were particularly visible in comparison to Large White pigs (P < 0.05), which showed higher amounts of these fatty acids. It should be mentioned that although Landrace pigs had higher amounts of PUFA than Duroc, they were significantly lower than LW, especially in regard to the contents of C20:3n-6, C20:4n-6 and C22:5n-3. Generally, concerning the amounts of polyunsaturated fatty acids the breeds could be placed in the following order Duroc < Landrace < Pietrain < Large White.

The total amounts of the fatty acids belonging to the different classes as well as two related nutritional indices is presented on Table 3. The total SFA were not affected by the breed, which could be explained with the different patterns of variation in C14:0 and C18:0 among breeds as well as the lack of discrepancy in the content of C16:0 which is the major saturated fatty acid in the muscle tissue. On the other hand, the total MUFA content

Table 2. Fatty acid composition (%FAME) of *m. Longissimus thoracis* in different pig breeds

Fatty acids	Landrace	Pietrain	Duroc	Large White	SEM	Sig.	rIMF
C14:0	1.57ab	1.54b	2.04a	1.49b	0.07	*	0.673***
C16:0	24.14	24.74	25.04	24.16	0.42	NS	0.231
C16:1Δ7	3.03	3.01	3.40	2.68	0.10	P = 0.1	0.491*
C18:0	12.71a	11.90b	11.84b	12.77a	0.12	***	-0.396
C18:1Δ9	34.27ab	31.93b	40.22a	29.36b	1.09	***	0.727***
C18:2n-6	18.01a	19.41a	13.03b	21.09a	0.89	**	-0.717***
C18:3n-3	0.84	0.96	0.86	0.95	0.04	NS	-0.217
C20:2n-6	0.45	0.54	0.48	0.58	0.02	NS	-0.258
C20:3n-6	0.44bc	0.47ab	0.30c	0.63a	0.03	***	-0.704***
C20:4n-6	3.80b	4.52ab	2.30c	5.12a	0.30	***	-0.758***
C20:5n-3	0.14ab	0.18ab	0.09b	0.22a	0.01	*	-0.527**
C22:5n-3	0.52bc	0.71ab	0.34c	0.88a	0.05	***	-0.699***
C22:6n-3	0.08	0.09	0.06	0.07	0.01	NS	-0.104

*P < 0.05, **P < 0.01; ***P < 0.001. Values connected with different letters differ significantly (P < 0.05)

Table 3. Total amounts of fatty acids and related lipid indices of *m. Longissimus thoracis* in the four breeds

Item	Landrace	Pietrain	Duroc	Large White	SEM	Sig.	rIMF
SFA	38.42	38.18	38.92	38.42	0.46	NS	0.217
MUFA	37.30b	34.94b	43.62a	32.04b	1.28	***	0.735***
PUFA	24.28ab	26.88a	17.46b	29.54a	1.15	**	-0.734***
n-6	22.70ab	24.94a	16.11b	27.42a	1.20	**	-0.739***
n-3	1.58ab	1.94ab	1.35b	2.12a	0.09	**	-0.590**
P/S	0.63ab	0.70a	0.45b	0.77a	0.04	**	-0.396*
n-6/n-3	14.37a	12.86ab	11.93b	12.93ab	0.33	*	-0.710***

*$P < 0.05$, **$P < 0.01$; ***$P < 0.001$. Values connected with different letters differ significantly ($P < 0.05$)

was determined by the amount of C18:1n-9 ($P < 0.001$) revealing highest values in Duroc when compared to the rest of the breeds ($P < 0.05$). PUFA however were lower in the muscle of this breed more pronounced in comparison to the Large White and Pietrain gilts ($P < 0.05$).

Due to the lowest amounts of PUFA, the P/S ratio in the muscle of Duroc pigs showed the lowest values, which was also found in regard to the n-6/n-3 for this breed.

As could be seen from Tables 2 and 3, the intramuscular lipids are closely related to the fatty acid profile. The increase of the total lipids was accompanied by higher contents of C14:0 and C18:1n-9, as well as C16:1n-7 and total MUFA, which was visible by the positive and significant correlations between the examined traits. On the other hand, the correlations between the intramuscular lipids and PUFAs were negative.

Discussion

The results of the study show that both lipid content of the muscle as well as the fatty acid profile differ among the studied breeds, as Duroc pigs are more distinguishable in regard to these traits. Since the pigs are fed the same diet, it could be concluded that the existing differences are largely attributable to the breed specificities. Duroc breed has been famous for its high intramuscular lipids. In the present study, the content of the intramuscular lipids in *m. LT* of the Durocs was 3.15% which is approximately 60% higher than the content determined in the other three breeds. Our results were confirmed by Suzuki et al. (2003) comparing Duroc and Berkshire as well as Choi et al. (2016) who compared Duroc, Yorkshire, Landrace and crossbred pigs. On the other hand, Warriss et al. (1990) found that Large White pigs and Pietrain exhibited the lowest intramuscular lipids in the Longissimus muscle among other commercial breeds, which is in line with our results. The lipid content of the muscles is closely related to the fatty acid profile which is confirmed by the high values of the correlation coefficients determined in this study between the majority of the SFA, MUFA and PUFA. These relations could explain the differences in the fatty acid profile observed among the breeds of interest. Although the total SFA amounts was not influenced by the breed, we found differences in some of the individual saturated fatty acids, particularly, in C14:0 and C18:0. The content of C14:0 was the highest in Duroc gilts (2.04%), and also highly significant positive correlation was found between this fatty acid and the lipid content ($r = 0.674$, $P < 0.001$). On the hand, Duroc pigs together with Pietrain displayed lower content of C18:0 than the gild of Landrace and Large white breeds. In agreement with our results, Klensporf-Pawlik et al. (2012) found that the content of C14:0 in longissimus muscle of Duroc gilts is higher than that of Pietrain, Polish Large White and Polish Landrace, however the content of C18:0 was higher only when compared with Pietrain pigs. Apart from the content of C14:0, significant positive correlations were found between the lipid content of *m. LT* and the levels of C16:1n-7 ($r = 0.491$, $P < 0.05$) and C18:1 n-9 ($r = 0.727$, $P < 0.001$). While C16:1 showed similar content in the four breeds and only tended to be higher in Duroc, the amounts of C18:1n-9 showed marked increase in the muscle of this breed and determined the higher total MUFA as well. No such relationship was observed by Choi et al. (2016) who found that Duroc pigs had lower C18:1 and MUFA despite the significantly highest intramuscular lipids. Similar to us, Vehovský et al. (2013) determined strong correlation between the intramuscular fat and the amount of MUFA in pigs. It could be suggested, that the higher C18:1n-9 and the associated higher MUFA content in Duroc pigs are due to increased Δ-9 desaturase activity which is positively related to the higher lipid content (Ntawubizi et al., 2009). Cameron and Enser (1991) found that Duroc pigs had higher content of MUFA in the muscles when compared to British Landrace and also lower PUFA amount. This is in line with our results and coincides with the strong negative correlations determined between the lipid content and the most individual and total polyunsaturated fatty acid in *m. LT*. This has also been observed by Pietruszka et al. (2015) in breeds with high and low lean meat percentage. Furthermore, the differences in the PUFA content could be explained by the different abilities of the breeds to elongate and desaturate the precursors C18:2n-6 and C18:3n-3 (Magowan et al., 2011). As it could be seen in the values of the ratio P/S in the four breeds in this study is above

0.4. This is mainly due to the significant amounts of C18:2n-6 which is the most abundant polyunsaturated fatty acid in the pig muscles. However, it is also the reason for the high values of n-6/n-3 PUFA which is this study varied in the range of 11.97-14.46, which is above the recommended limit of 4 (Simopoulos, 2004). Generally, the high values of n-6/n-3 in the pigs could be explained with the composition of their diets that are rich in cereals and are not uncommon. In comparison between four breeds Wood et al. (2004) determined the values of n-6/n-3 in neutral lipids of *m. LD* within the range of 10.54-12.23 and in the phospholipids 9.41-10.99. The lowest values of n-6/n-3 for the neutral lipid fraction was found in Duroc pigs.

Conclusions

The results of the study showed that Duroc pigs had the highest content of C14:0, C18:1n-9 and total MUFA in *m. LT*, while Pietrain and Large White displayed the lowest levels of these fatty acids. The content of C18:0 was higher in Large White and Landrace, when compared to Duroc and Pietrain. Furthermore, Duroc pigs displayed the lowest contents of both individual and PUFA, as this was visible especially in comparison with the fatty acid profile of the Large White and correlated to the content of the total lipids in the muscle. This pattern determined the lowest values of n-6/n-3 in Duroc, however, in regard to the ratio between poly- and saturated fatty acids, the most favorable values were found in the *LT* muscle of Pietrain and Large White pigs. We conclude that the differences in the lipid profile that exist between the breeds could be important for the further crossbreeding aiming to favourably manipulate the fatty acid composition for producing of meat with high nutritional and healthy value.

Acknowlegements

The authors would like to express their gratitude to Dr. Milenka Dimitrova, Mr. Tihomir Todorov and Mr. Nikolay Vasilev from Golyamo Vranovo Invest AD for their kind support in this work.

The publishing of the present scientific paper is co-financed by National Science Fund, contract No. 01/19 from 23.08.2017.

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Received: December, 20, 2018; *Accepted*: January, 4, 2019; *Published*: December 31, 2020