Carcass traits and meat quality of pigs fed on fodder supplemented with sunflower oil or conjugated linoleic acid

Cechy tuszy oraz jakość mięsa świń żywionych paszą z dodatkiem sprzężonego kwasu linolowego lub oleju słonecznikowego

Pavel NEVRKLA[1], Marie ČECHOVÁ[1], Przemysław Dariusz WASILEWSKI[2]*, Grażyna MICHALSKA[2] and Jerzy NOWACHOWICZ[2]

[1]Mendel University in Brno, Faculty of Agronomy, Department of Animal Breeding, 61300 Brno, Czech Republic

[2]University of Science and Technology in Bydgoszcz, Faculty of Animal Breeding and Biology, Department of Poultry Breeding and Animal Products Evaluation, ul. Mazowiecka 28, 85-084 Bydgoszcz, Poland, *correspondence: surzwierz@utp.edu.pl

Abstract

The aim of the study was to compare meat and fat content and meat quality of pigs fed diet supplemented with sunflower oil (SFO) or conjugated linoleic acid (CLA) and animals not receiving the supplement SFO or CLA (control group). The experiment consisted of 116 pigs, divided into three groups: two experimental (n = 40) where animals were fed feed supplemented with 2% sunflower oil (SFO) or conjugated linoleic acid (CLA) and control (n = 36). Fattening pigs were kept and fed in standardized conditions. The animals were slaughtered at a body weight of 120 kg. Meat quality traits (pH, drip loss, backfat fat content, colour, MLLT muscle dry matter content, fat in the dry matter, IMF in MLLT) were determined. Summarizing obtained results it should be concluded that 2% sunflower oil or conjugated linoleic acid did not affect the meat quality. The experimental animals were characterized by high meat content (58.26% - SFO addition; 57.63% - CLA addition; 57.99% C group) and low fat content (from 14.35 mm in SFO group up to 14.70 mm in CLA group).

Keywords: drip loss, meat colour, pH value

Abstrakt

Celem badań było porównanie umięśnienia i otłuszczenia oraz jakości mięsa świń żywionych paszą z dodatkiem oleju słonecznikowego (SFO) lub sprzężonego kwasu linolowego (CLA) oraz zwierząt nie otrzymujących dodatku SFO lub CLA (grupa kontrolna). Eksperyment obejmował 116 świń mieszańców, podzielonych na 3 grupy: 2 doświadczalne (n = 40) w których zwierzęta były żywione paszą z 2% dodatkiem oleju słonecznikowego (SFO) lub sprzężonego kwasu linolowego (CLA) i kontrolną (n = 36). Tuczniki były utrzymywane i żywione w ujednoliconych warunkach. Zwierzęta zostały ubite przy masie ciała 120 kg. Określono cechy jakości mięsa (pH, wyciek swobodny soku, zawartość tłuszczu w słoninie, barwa, zawartość suchej masy w mięśniu MLLT, tłuszcz w suchej masie, IMF w MLLT). Podsumowując uzyskane wyniki należy stwierdzić, że 2% dodatek oleju słonecznikowego lub sprzężonego kwasu linolowego nie wpłynął na jakość mięsa. Badane zwierzęta charakteryzowały się wysoką mięsnością (58,26 % - dodatek SFO, 57,63 % – dodatek CLA oraz 57,99 % - grupa kontrolna) i niewielkim otłuszczeniem (od 14.35 mm w grupie SFO do 14.70 mm w grupie CLA).

Słowa kluczowe: barwa mięsa, wartość pH, wyciek swobodny soku

Introduction

Modern consumers are interested in health-promoting food, especially pork with a high lean meat and low fat content, and adequate technological and consumerist quality. Therefore, the main target in breeding and rearing pigs has always been to achieve low fat and high meaty animals and preserving a satisfactory quality of their meat (Eggert et al., 1998) at the same time. A pork quality is determined by many factors - genetic and environmental, including nutrition. The use of fodder additives such as conjugated linoleic acid (CLA) may be one way to improve health benefits and pork quality (Wiegand et al., 2002). According to Koba and Yanagita (2014), physiological effects of CLA are antimutagenic, anticarcinogenic, reduction of body fat, antidiabetic, prevention of atherosclerosis, enhancement of immune function, antihypertensive – as presented by in vitro and in vivo studies of different species (pigs and rodents). Previous studies showed that pigs fed ration with addition of conjugated linoleic acid and sunflower oil had more desirable fatty acid profile in the loin muscle and backfat (Čechová et al., 2012; Wasilewski et al., 2011, 2012, 2014).

In meat processing, a raw material quality is very important, especially a pH value of meat tissue, water holding capacity (WHC), an amount of muscle drip loss and meat colour (Koćwin-Podsiadła et al., 2006). The addition of CLA and SFO may impact on slaughter value (carcass weight, meat content) and meat quality traits (pH_1, pH_{24}, drip loss) of pigs (Čechová et al., 2010; Martin et al., 2008). The pH value through its impact on muscle proteins, is the main determinant of the quality of the meat, affecting the water holding capacity, colour, tenderness, flavour, durability and a shelf life. It is used to diagnose the proper process of glycolysis, as well as to detect the PSE and DFD meat (Van Laack et al., 2001). The colour is also one of the main

distinctions of the pork quality (Twarda and Dolatowski 2006). It depends mainly on the presence of pigment in the meat, as well as its tissue composition and structure of the muscle tissue. The meat colour is crucial in consumer preferences and shows significant correlations with other traits of the meat (Kortz et al., 2000).
The aim of the paper is to determine the meat and fat content and the meat quality of pigs fed fodder supplemented with sunflower oil or conjugated linoleic acid.

Material and methods

Experimental animals and diets

The experiment was conducted in the Czech Republic in Bonagro a.s. an agricultural company. It covered 116 crossbred pigs (PLEBO hybrids Brno). They were divided into three groups: two experimental (n = 40 - 20 gilts and 20 barrows) and control (n = 36 – 19 gilts and 17 barrows).
Varied diets were used according to the following scheme:
Group:

1 – Diet of 2.0% amount of sunflower oil (SFO)
2 – Diet of 2.0% amount of conjugated linoleic acid (CLA)
3 – Control diet (C)

The experiment was carried out in farm conditions. Pigs were housed in common fattening stable and were fed standard feed mixture for fattening pigs. The live weight of pigs was controlled at the beginning of the experiment. All pigs were from the 2nd and 3rd litter. Pigs were housed in the same compartment and subdivided into 4 pens within each group (10 pigs in each pen). They were not replicated.

At the beginning of the experiment the pigs were individually weighed, numbered and grouped by gender. All pigs were fed control diet before the start of the experiment. The start of diet 1 and 2 began when the weight of the pigs was 82 kg, on average. Pigs were slaughtered on different days according to their body weight, when the mean body weight of pen was 120 ± 5 kg. Conditions of the maintenance, care and nutrition of all experimental fatteners were standardized. The source of conjugated linoleic acid was a Luta-CLA® 60 preparation made by BASF consisting of CLA (C 18:2) containing min. 56%, including c9 t11 isomer min. 28% and t10 c12 isomer min. 28%. The diet was available *semi ad libitum* (feed available ad libitum in determined periods of time). A feed intake has not been evaluated. Ingredients of the diets are shown in Table 1. It was prepared in Bonagro a.s.

Table 1. Ingredients of the diets (%)

Tabela 1. Skład paszy (%)

Ingredients	Group		
	1 – SFO	2 - CLA	3 – C
Wheat	10.0	10.0	10.0
Wheat bran	10.0	10.0	10.0
Soybean meal	10.0	10.0	10.0
Mikrop A1-CDP-19	2.6	2.6	2.6
Corn	65.4	65.4	67.4
Sunflower oil	2.0	-	-
Conjugated linoleic acid	-	2.0	-
Total	100	100	100

Mikrop A1-CDP-19 Mineral vitamin premix
Mikrop A1-CDP-19 Premix mineralno-witaminowy

Data collection and analysis

The carcasses were weighed with accuracy of 0.1 kg, 30 minutes after slaughter. To determine the percentage of meat in carcass, intramuscular fat (IMF) content and the height of loin eye in the measurement point - *Musculus longissimus lumborum et thoracis* - (MLLT) FAT-O-MEATer (SFK – Technology DK 2730 Herlen, Denmark) was used. The backfat thickness was measured on the left half-carcass between 2nd and 3rd last rib, 70 mm from the medial line.

pH measurement was done using GRYF 107 LI portable probe equipped with THETA 90 - HC 123 glass electrode at the height of the last thoracic vertebra of MLLT.
The meat drip loss was determined using Honikel method (1987).

To measure meat colour (L*a*b*) a CM 2600d spectrophotometer (Konica Minolta, Japan) was used. CM 2600d was calibrated according to the methodology.

The chemical composition analysis of MLLT and backfat was conducted in The Laboratory of the Department of Morphology, Physiology and Animal Genetics, at Mendel University in Brno.

A computer program Statistica 8.0 PL (2008) was used to calculate mean ($\bar{x}$) and standard deviation (s). The significance of differences between tested groups was verified by Duncan's test.

Results

Carcass characteristics

Table 2 presents the results of lean meat and fat content, traits characterizing meat quality and significance of differences between 3 examined groups of animals.

Table 2. Carcass characteristics and traits of pork quality

Tabela 2. Charakterystyka półtusz i cechy jakości

Trait	Group		
	1 - SFO	2 - CLA	3 - C
Number	40	40	36
Warm carcass weight, kg	96.60±6.22^{A}	93.69±7.25	91.58±7.51^{B}
Backfat thickness, mm	14.35±3.36	14.70±3.31	14.53±2.68
Height of loin eye, mm	68.93±7.04	66.30±5.68	68.06±5.41
Lean meat content, %	58.26±2.70	57.63±2.65	57.99±2.03
pH_1 of muscles 45 minutes after slaughter	6.09±0.33	6.22±0.31	6.12±0.25
pH_{24} of muscles 24 hours after slaughter	5.64±0.07^{A}	5.75±0.15^{B}	5.78±0.20^{B}
48 hours drip loss, %	2.84±0.96	2.48±0.74	2.54±1.03
Backfat dry matter content, %	91.88±2.67^{a}	89.63±3.65^{b}	90.25±2.95
Backfat fat content, %	81.79±3.29	80.25±4.74	79.60±4.84
L* value of muscle	61.21±5.20	60.85±5.28	60.02±4.91
a* value of muscle	4.00±2.15^{a}	3.54±2.27	2.86±1.80^{b}
b* value of muscle	14.12±1.84	13.88±2.30	13.25±2.02
Muscle dry matter content, %	27.43±1.01^{A}	27.20±1.00^{a}	26.75±0.82^{Bb}
Muscle fat dry matter content, %	0.62±0.22	0.54±0.16	0.63±0.20
Muscle fat content (IMF), %	4.00±1.37	3.51±1.01	3.63±1.11

Averages in rows marked by different letters differ significantly between each other;
A, B – P ≤ 0.01; a, b – P ≤ 0.05
Średnie w rzędach oznaczone różnymi literami różnią się istotnie od siebie;
A, B – P ≤ 0,01; a, b – P ≤ 0,05

The highest warm carcass weight had fatteners from group 1, which was given the sunflower oil – SFO, intermediate weight had animals fed on the diet with conjugated linoleic acid – CLA, and the lowest had animals from group 3 – control group - C. The difference between groups 1 and 3 amounted to 5 kg and was significant ($P \leq 0.01$). The fatteners fed on the diet with CLA addition obtained the intermediate warm carcass weight among the above mentioned groups. The backfat thickness characterizing carcass fat content was small and balanced.

The lowest height of loin eye was measured in the group of pigs given CLA as the fodder supplement. In the remaining two groups this value was higher. However, the differences in this range were not significant. The meat content of fatteners was high and balanced in all groups. The differences between groups were not statistically confirmed.

Selected traits of pork quality

The pH value measured 45 minutes after the slaughter in the MLLT muscle was rather similar in all experimental groups. After 24 hours from the slaughter, the lowest pH value was measured in the group of fatteners receiving SFO as the fodder supplement. In the CLA group and in the control group the pH value was similar. The differences between group 1 (SFO) and groups 2 (CLA) and 3 (C) were significant ($P \leq 0.01$).

The drip loss measured 24 hours after slaughter did not differ between experimental groups. The backfat dry matter content was of the highest value in the group of pigs fed fodder with sunflower oil supplementation. The lowest value was found in the group of animals receiving conjugated linoleic acid. The differences in this range amounted to 2.25% and were confirmed as significant ($P \leq 0.05$).

Similarly, the highest amount of backfat fat content was found in the group of pigs receiving sunflower oil. The lowest content was observed in the control group, but those differences were not confirmed as significant.

All three parameters of the L*a*b colour of MLLT muscle were of the highest value in group 1 of animals fed fodder supplemented with sunflower oil – SFO; intermediate value was found in group 2 (CLA) however, the lowest value in the control group 3 – C. Only in the case of a* value a significant difference was confirmed between group 1 and 3.

Similarly, the MLLT muscle dry matter content was the highest in the group of pigs receiving sunflower oil, and the control group had the lowest content. Between these groups highly significant difference was verified. Also between the groups receiving CLA and the control group significant differences were proved.

The amount of fat in the dry matter was similar in the group of animals receiving sunflower oil and in the control group. The lowest amount was found in the group of individuals receiving conjugated linoleic acid.

The amount of intramuscular fat (IMF) in MLLT muscle was the highest in the group receiving SFO, and the lowest in the group of pigs fed on the fodder with CLA supplement. However, the differences in this range were not confirmed.

Discussion

Meat and fat content in pig carcasses

The pigs' meat content in the study was high and amounted approximately 58% (58.26% - SFO addition; 57.63% - CLA addition; 57.99% C group) and backfat thickness characterizing a fat content of carcass was low (from 14.35 mm in SFO group up to 14.70 mm in CLA group).

The results of other authors show a lower fat content of animals receiving CLA supplementation (Dugan et al., 1997; Eggert et al., 2001; Thiel-Cooper et al., 2001; Wiegand et al., 2001; D'Souza and Mullan, 2002; Dunshea et al., 2002; Tischendorf et al., 2002; Wiegand et al., 2002; Corino et al., 2003; Ostrowska et al., 2003) and an increase of the loin eye area (Eggert et al., 2001; Gatlin et al., 2002; Wiegand et al., 2001, 2002).

It seems that sunflower oil, which is oil with a high concentration of the valuable polyunsaturated fatty acids necessary for the proper development of animals, affected the formation of warm carcass weight, which was the largest in the SFO group.

pH value, drip loss, colour of muscle, backfat dry matter and intramuscular fat content

The results of some authors may suggest that the pursuit of maximum meat content and minimum fat content of pigs affects the levels of some traits, such as those related to meat quality (Przybylski et al., 2007). The present study took into account the most important quality factors of meat, including meat pH measured 45 minutes [pH_1] and 24 hours [pH_{24}] after slaughter. The results of the pH of MLLT muscle measured 45 minutes after slaughter (pH_1) ranged from 6.09 (SFO) up to 6.22 (CLA) and were not significantly diversed among the tested groups of pigs. The pH_{24} value of LD muscle of pigs from the groups CLA and C was significantly higher, thus more favourable than SFO group. The results in range of pH_1 and pH_{24} of MLLT muscle of the three tested groups of animals should be considered as satisfactory and in line with criteria set by Koćwin-Podsiadła et al. (2006) indicating normal meat ($pH_1 \geq 6.0$ and pH_{24} 5.4-5.9), which is the most desirable.

Eggert et al. (2001) and Corino et al. (2003) did not observe the impact of CLA supplementation on pH value measured 24 hours after animal slaughter. Also Wasilewski et al. (2009) on the base of obtained results proved that feeding pigs with an addition of conjugated linoleic acid in amount of 0.5; 1.0 and 2.0% did not affect the meat quality.

The meat drip loss results of tested groups of pigs were favourable and on an even level (from 2.48% - CLA addition - up to 2.84% SFO addition), showing normal meat (Pospiech et al., 1998).

All three paramaters of the L*a*b colour of MLLT muscle were of the highest value in group 1 (SFO), intermediate in group 2 (CLA) and the lowest in group 3 (C). However, only in the case of a* value the results were confirmed as significant between groups 1 and 3. Similar results were obtained by Corino et al. (2003), who did not observe differences in the colour of Longissimus dorsi and

Semimembranosus muscles in pigs receiving an addition of conjugated linoleic acid compared with the animals from the control group. Also Wasilewski et al. (2010) did not prove the colour change of Semimembranosus muscle as a result of the addition of conjugated linoleic acid in the amount from 0.5 to 2%. The results of meat colour (L *) obtained in the present study seem to confirm the hypothesis that the high meat content of carcasses may be associated with a lighter colour (Daszkiewicz and Wajda 2002).

The backfat dry matter content of pigs fed fodder with SFO addition was significantly higher (by 2.25%) than the CLA group. The LD dry mater content was significantly higher in the experimental groups SFO and CLA than in the control group C.

The amount of intramuscular fat in MLLT muscle of pigs from tested groups was on high and even level. It should be noted that the amount of intramuscular fat impacts on the pork meat taste and its amount lower than 1% is assumed to be unacceptable causing deterioration of the palatable values of pork (Schwörer et al., 2000).

Conclusions

Summarising obtained results, it should be noted that examined animals had a high meat and low fat contents. The meat from pigs representing three examined groups was of normal quality. Therefore, the experimental factors as diets with 2% addition of sunflower oil – SFO (group 1) and conjugated linoleic acid – CLA (group 2) did not impact on the meat quality. Better results can be seen regarding to meat quality traits in groups: receiving an addition of conjugated linoleic acid (CLA) and control group (C) compared with group fed fodder with SFO addition.

Acknowledgements

This study was supported by project No. QI 111A166 which is financed by the Ministry of Agriculture of the Czech Republic and internal grant project of Mendel University IGA TP 5/2014.

References

Corino, C., Magni, S., Pastorelli, G., Rossi, R., Mourot, J. (2003) Effect of conjugated linoleic acid on meat quality, lipid metabolism, and sensory characteristics of dry-cured hams from heavy pigs. Journal of Animal Science, 81 (9), 2219-2229.

Čechová, M., Bečková, R., Hadaš, Z., Václavková, E., Rychetská, M. (2010) Effect of CLA and sunflower oil in pig diet on carcass value traits and meat quality. Research in Pig Breeding, 4 (1), 1-4.

Čechová, M., Hadaš, Z., Nowachowicz, J., Wasilewski, P. D. (2012) The effect of feed with the addition of conjugated linoleic acid or sunflower oil on fatty acid profile of crossbred pigs meat. Bulgarian Journal of Agricultural Science, 18 (6), 827-833.

D'Souza, D. N., Mullan, B. P. (2002) The effect of genotype, sex and management strategy on the eating quality of pork. Meat Science, 60 (1), 95-101. http://dx.doi.org/10.1016/S0309-1740(01)00112-7

Daszkiewicz, T., Wajda, S. (2002) Jakość mięsa z tusz tuczników zaliczonych do klasy E, U, i R w systemie klasyfikacji EUROP. Prace i Materiały Zootechniczne, Zeszyt Specjalny, 13, 31-35. [in Polish]

Dugan, M. E. R., Aalhus, J. L., Schaefer J. A. L., Kramer, J. K. G. (1997) The effect of conjugated linoleic acid on fat to lean repartitioning and feed conversion in pigs. Canadian Journal of Animal Science, 77 (4), 723-725. http://dx.doi.org/10.4141/A97-084

Dunshea, F. R., Ostrowska, E., Luxford, B., Smits, R. J., Campbell, R. G., D'Souza, D. N., Mullan, B. P. (2002) Dietary conjugated linoleic acid can decrease backfat in pigs housed under commercial conditions. Asian-Australasian Journal of Animal Sciences, 15 (7), 1011-1017. http://dx.doi.org/10.5713/ajas.2002.1011

Eggert, J. M., Belury, M. A., Kempa-Steczko, A., Mills, S. E., Schinckel, A. P. (2001) Effects of conjugated linoleic acid on the belly firmness and fatty acid composition of genetically lean pigs. Journal of Animal Science, 79 (11), 2866-2872.

Eggert, J. M., Belury, M. A., Schinckel, A. P. (1998) The effects of conjugated linoleic acid (CLA) and feed intake on lean pig growth and carcass composition. Purdue University Swine Day Reports, 1998, 21-25.

Gatlin, L. A., See, M. T., Larick, D. K., Lin, X., Odle, J. (2002) Conjugated linoleic acid in combination with supplemental dietary fat alters pork fat quality. Journal of Nutrition, 132 (10), 3105-3112.

Honikel, K. O. (1987) The water binding of meat. Fleischwirtschaft, 67, 9, 1098-1102.

Koba, K., Yanagita, T. (2014) Health benefits of conjugated linoleic acid (CLA). Obesity Research & Clinical Practice, 8 (6), e525-e532. http://dx.doi.org/10.1016/j.orcp.2013.10.001

Koćwin-Podsiadła, M., Krzęcio, E., Przybylski, W. (2006) Pork quality and methods of its evaluation – a review. Polish Journal of Food and Nutrition Sciences, 15/56 (3), 241-248.

Kortz, J., Kapelański, W., Grajewska, S., Kurył, J., Bocian, M., Rybarczyk, A. (2000). Meat quantity to meat quality relations when the RYR1 gene effect is eliminated. In: C. Wenk, J. A., Fernandez, M. Dupuis, eds. (2000) Quality of meat and fat in pigs as affected by genetics and nutrition. EAAP publicatication No. 100. The Nederlands: Wageningen Academic Publishers, 143-146.

Martin, D., Muriel, E., Gonzalez, E., Viguera, J., Ruiz Carrascal, J. (2008). Effect of dietary conjugated linoleic acid and monounsaturated fatty acids on productive, carcass and meat quality traits of pigs. Livestock Science, 117 (2-3), 155-164. http://dx.doi.org/10.1016/j.livsci.2007.12.005

Ostrowska, E., Cross, R. F., Muralitharan, M., Bauman, D. E., Dunshea, F. R. (2003) Dietary conjugated linoleic acid differentially alters fatty acid composition and increases conjugated linoleic acid content in porcine adipose tissue. British Journal of Nutrition, 90 (5), 915-928. http://dx.doi.org/10.1079/BJN2003982

Pospiech, E., Borzuta, K., Łyczyński, A., Płókarz, W. (1998) Meat defects and their economic importance. Polish Journal of Food and Nutrition Sciences, 7/48(4S), 7-20.

Przybylski, W., Jaworska, D., Czarniecka-Skubina, E., Półtorak, A., Niemyjski, S. (2007) Analysis of conditionality of sensory quality Longissimus lumborum muscle after heat treatment. Electronic Journal of Polish Agricultural Universities, Food Science and Technology, 10, 4.

Schwörer, D., Hofer, A., Lorenz, D., Rebsamen, A. (2000) Selection progress of intramuscular fat in Swiss pig production. In: C. Wenk, J. A., Fernandez, M. Dupuis, eds. (2000) Quality of meat and fat in pigs as affected by genetics and nutrition. EAAP publicatication No. 100. The Nederlands: Wageningen Academic Publishers, 69-72.

Thiel-Cooper, R. L., Parrish, F. C., Sparks, J. C., Wiegand, B. R., Ewan, R. C. (2001) Conjugated linoleic acid changes swine performance and carcass composition. Journal of Animal Science, 79 (7), 1821-1828.

Tischendorf, F., Schone, F., Kirchheim, U., Jahreis, G. (2002) Influence of a conjugated linoleic acid mixture on growth, organ weights, carcass traits and meat quality in growing pigs. Journal of Animal Physiology and Animal Nutrition 86 (3-4), 117-128. http://dx.doi.org/10.1046/j.1439-0396.2002.00366.x

Twarda, J., Dolatowski, Z. J. (2006) The effect of sonication on the colour and WHC of normal and PSE pork. Animal Science, 1, 184-185.

Van Laack, R. L. J. M., Kauffman, R. G., Greaser, M. L. (2001) Determinants of ultimate pH of meat. Proceedings of 47th International Congress of Meat Science and Technology, Kraków, 22-26.

Wasilewski, P. D., Michalska, G., Cechova, M., Nevrkla, P. (2014) Change of the backfat fatty acid profile of crossbred pigs fed with the fodder with addition of sunflower oil and conjugated linoleic acid. Bulgarian Journal Agricultural Science, 20 (2), 226-231.

Wasilewski, P. D., Nowachowicz, J., Michalska, G., Bucek, T., Lynch, B., Mullen, A.M. (2010) Colour of meat of pigs fed the fodder with addition of conjugated linoleic acid. Pig Meat. Modern trends in meat production. Polskie Towarzystwo Technologów Żywności, Oddział Małopolski, 117-121.

Wasilewski, P. D., Nowachowicz, J., Michalska, G., Bucek, T., Lynch, B., Mullen, A. M. (2011) Fatty acid profile of Longissimus dorsi muscle of crossbred pigs fed with addition of conjugated linoleic acid or sunflower oil. Archiv Tierzucht, 54, 1, 61-68.

Wasilewski, P. D., Nowachowicz, J., Michalska, G., Bucek, T., Lynch, B., Mullen, A.M. (2012) Backfat fatty acid profile of crossbred pigs fed a diet supplemented with conjugated linoleic acid or sunflower oil. Annals of Animal Science, 12 (3), 433-443. http://dx.doi.org/10.2478/v10220-012-0037-z

Wasilewski, P. D., Nowachowicz, J., Michalska, G., Lynch, B., Mullen, A. M. (2009) The impact of conjugated linoleic acid addition on pH value of longissimus dorsi muscle. Journal of Central European Agriculture, 10 (1), 53-56.

Wiegand, B. R., Parrish, F. C., Swan, J. E., Larsen, S. T., Baas, T. J. (2001) Conjugated linoleic acid improves feed efficiency, decreases subcutaneous fat, and improves certain aspects of meat quality in Stress-Genotype pigs. Journal of Animal Science, 79 (8), 2187-2195.

Wiegand, B. R., Sparks, J. C., Parrish, F. C., Zimmerman, D. R. (2002) Duration of feeding conjugated linoleic acid influences growth performance, carcass traits, and meat quality of finishing barrows. Journal of Animal Science, 80 (3), 637-643