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Factors affecting the fatty acid composition and fat oxidative stability in pigs

Faktory ovlivňující kompozici mastných kyselin a oxidační stabilitu tuku prasat

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Abstract

The aim of the study was to evaluate the effect of selected factors affecting fatty acids (FA) composition in pig fat. In the experiment, the influence of nutrition, gender, carcass weight, lean meat proportion (LMP) and intramuscular fat (IMF) were monitored. The effect of diet, specifically the influence of added linseed or corn on the fatty acids composition in the backfat was studied in pigs. From the perspective of the required increase of polyunsaturated fatty acids (PUFA) only the addition of the linseed proved to have a significant effect.

Another evaluated aspect concerning the FA spectrum was the gender. While the backfat in barrows showed higher ($P \leq 0.05$) amount of monounsaturated fatty acids (MUFA), the backfat in gilts displayed a significantly higher proportion ($P \leq 0.01$) of the PUFA and total unsaturated fatty acids (UFA). A significant effect on the PUFA proportion has also been demonstrated for the lean meat proportion (LMP) parameter, which therefore represents not only a qualitative carcass meat parameter but also plays an important role in relation to the FA composition in the fat in pigs.

In connection to the FA proportion changes the study also monitored the fat oxidative stability with the use of the TBARS method. Concerning the oxidative stability the effects of nutrition, FA groups, gender, carcass weight and LMP were studied. The relationship between the above mentioned factors and oxidative stability was found to be insignificant.

Keywords: backfat, barrows, gilts, nutrition, PUFA

Abstrakt

Cílem práce bylo posoudit efekt vybraných faktorů, které ovlivňují zastoupení mastných kyselin (MK) v tuku prasat. V pokuse byl sledován vliv výživy, pohlaví, hmotnosti jatečného trupu, podílu libové svaloviny a intramuskulárního tuku. Při hodnocení efektu výživy byl hodnocen vliv doplňku lněného semene resp. kukuřice

v krmné směsi na složení mastných kyselin ve hřbetním tuku prasat. Z hlediska požadovaného navýšení polyenových mastných kyselin (PUFA) se jako významný zdroj projevil pouze doplněk lněného semene. Dalším aspektem hodnocení MK spektra bylo pohlaví. Zatímco hřbetní tuk vepříků obsahoval vyšší (P≤0,05) množství monoenových mastných kyselin (MUFA), tuk prasniček obsahoval významně více (P≤0,01) polyenových mastných kyselin a celkových nenasycených MK (UFA). Signifikantní vliv na podíl PUFA má také podíl libové svaloviny, který proto nepředstavuje jen kvalitativní parametr libovosti jatečného těla prasat, ale má význam i ve vztahu ke kompozici MK v tuku prasat. V návaznosti na změnu v zastoupení mastných kyselin v tuku byla zjišťována oxidační stabilita tuku metodou TBARS. Ve vztahu k oxidační stabilitě byl sledován vliv výživy, skupin MK, pohlaví, hmotnost jatečného trupu (JUT) a podílu libové svaloviny. Vztah mezi vyjmenovanými faktory a oxidační stabilitou byl vyhodnocen jako nevýznamný.

Klíčová slova: hřbetní tuk, vepříci, prasničky, výživa, PUFA

Introduction

Apart from the high nutritional value pork meat is also valued for its attractive sensory properties. The content (proportion) and structure of intramuscular fat (IMF) belong among one of the key determinants of the sensory properties. The fat contained in the pork meat is also an important dietary component in human nutrition. It serves as a source of unsaturated fatty acids, which act as precursors of many biologically active substances in humans. In this aspect the polyunsaturated fatty acids (PUFA) are considered to be extremely important, especially the FA belonging in the n-3 line, which is gained from the vegetable portion of diet and utilized by the pig organism. While PUFA (especially linoleic and a-linolenic acid) effectively decrease the risk of cardiovascular diseases, the saturated fatty acids (such as lauric, myristic and palmitic acid) significantly increase the incidence of cardiovascular diseases through the process of increased plasma LDL levels.

The structure of FA contained in lipids affects the final compounds produced by lipid oxidation and also the speed of the oxidative process initiation. High concentration of certain substances, such as PUFA, leads to an increased speed of this undesirable process. Lipid oxidation represents major problem causing the decrease in fat quality and therefore decrease in the quality of meat. The process of lipid oxidation is accompanied by rancid odor and loss of palatability of the final meat product. In addition some of the lipids degradation products are, according to literature, considered to be mutagenic, carcinogenic or cytotoxic. Fatty acids of lipids thus affect a wide range of quality attributes such as the color stability, drip loss and development of oxidative rancidity (Ruban et al., 2009).

The susceptibility of unsaturated FA (especially PUFA) to oxidation is the main cause of a different attitude of meat consumers and meat processors toward this issue. While the consumers find higher PUFA content very desirable, the meat processors consider PUFA to be a somewhat less preferred component due to their ability to change the structure and consistency of meat products as well as their shorter viability (Warnants, 1999).

The objective of this study is to evaluate the selected factors affecting the FA composition in the fat and subsequently the meat oxidative stability in pigs.

Materials and Methods

Animals

The experiment was carried out at the Pig Testing Station in Ploskov-Lány. The experiment involved a total amount of 72 hybrid pigs of the Large white$_S$ × (Large white$_D$ × Landrace) genotype and balanced gender (barrows/gilts). The pigs were penned at an average age of 69 days from the birth and at an average live weight of 28.7 kg. Housing and penning of pigs was carried out in pairs in accordance with a uniform methodology applicable for testing of domestic and foreign programs concerning the pig breeding in the Czech Republic (Smolák, Ivánek, 1992). Upon reaching the live average body weight of 110 kg all of the pigs were slaughtered.

Nutrition and feeding

For the duration of the experiment the pigs were fed by complete feed mixture (CFM) ad-libitum according to the methodology for the testing of pigs. CFMs were composed of the following components: wheat, barley, soybean meal and premix. According to the CFM composition the pigs were divided into 3 groups. The control group (CON), experimental L (linseed addition) and experimental C (corn addition) group. The transitions of CFM were carried out continuously during the test. CFM nutrient composition is shown in the Table 1.

Table 1. The diet component proportions (%)

Component	LW 25 – 35kg			LW 35 – 65kg			LW 65 – 110kg		
	CON	C	L	CON	C	L	CON	C	L
Wheat	40.00	26.50	28.10	44.55	38.38	30.74	45.34	40.36	31.25
Barley	38.30	30.00	40.00	39.49	32.88	40.00	39.70	33.36	40.00
Soybean	18.20	20.00	13.70	12.46	12.80	11.11	11.46	11.60	10.66
Corn	-	20.00	-	-	12.80	-	-	11.60	-
Linseed	-	-	15.00	-	-	15.00	-	-	15.00
Premix	3.50	3.50	3.20	3.50	3.14	3.15	3.50	3.02	3.09

LW - Live weight ; CON - control group; C - group with the addition of corn; L - group with the addition of linseed

Carcass value

The meat samples representing the FA profile in the IMF and backfat were collected from the loin of the right carcass halves, homogenized and subsequently subjected to chemical analysis. The basic chemical analysis focused on determining the following values: water content (gravimetric determination of the weight difference between the samples before and after being dried with sea sand), IMF and subcutaneous fat (gravimetric determination following the petroleum ether extraction).

Fatty acid methyl esters were determined following the extraction of total lipids carried out according to Folch et al. (1957). Methanolysis was performed by applying the cathalytic effect of potassium hydroxide and extraction of acids in the form of methyl esters in heptane. The contents of isolated methyl esters were determined using a gas chromatograph (Master GC, Dani Instruments S.p.A., Cologno Monzese, Italy) equipped with a flame ionisation detector and a column with polyethylene glycol

as the stationary phase (FameWax; 30 m×0.32 mm×0.25 μm). Helium was used as the carrier gas, with a flow rate of 5 ml*min^{-1} and a split ratio of 1:9.

The analysis was carried out under the following temperature conditions: injection temperature 50 °C (2 minutes), temperature increase by 10°C to 1 minute up to 230 °C (holding time 8 minutes), detector temperature 220 °C.

The obtained records were analysed using the Clarity 5.2 program and quantified on the basis of known retention times from a standard Food Industry FAME Mix from the Restek Corporation (Bellefonte, PA, USA).

The oxidative stability was determined according to the Salih et al. (1987) with the use of thiobarbituric number (TBA). The method uses the content of malondialdehyde, a secondary product of lipid oxidation, which after isolation reacts with 2-thiobarbituric acid creating a pink colour.
The color intensity of the resulting complex was measured by spectrophotometry and subsequently, based on the formula *c*20*72/m*1000*, (where *c* is the content of MDA in nmol*5ml, *m* is a sample portion), the TBARS value was calculated (mg*kg^{-1}).

Statistical analysis

The results of the experiment were evaluated with the statistical program SAS® Propriety Software Release 6.04 (2001) using analysis of variance (ANOVA) function. The differences between the individual traits were tested *via* a GLM procedure.

Results

Table 2 presents the selected factors influencing the FA representation of fat in pigs. From that it is clear that with the increasing carcass weight the SFA proportion increases as well (P≤0.05), while the UFA proportion decreases (P≤0.05). The content of MUFA is also significantly influenced (P≤0.01) by the addition of corn or by the LMP in the carcass body. The LMP parameter was also evaluated as significant regarding the PUFA (P≤0.05) and MUFA (P≤0.01) content. When evaluating the FA spectrum of the backfat there were significant differences found in relation to the gender (Table 4) for the MUFA and PUFA content. The barrows showed significantly higher values of the MUFA content (P≤0.05) while the gilts showed significantly higher values of the PUFA content (P≤0.01).

Table 2. Statistical significance of the influence of selected factors that affect the fatty acid representation (% of total fatty acids)

Factor	SFA	MUFA	PUFA	UFA
Linseed	<.0001	<.0001	<.0001	<.0001
Corn	0.4195	0.0044	0.1093	0.3995
Carcass weight	0.0275	0.1098	0.3001	0.0275
Sex	0.1194	0.0322	0.0014	0.102
Lean meat proportion (LMP)	0.9654	0.0039	0.0141	0.9794
Intramuscular fat	0.2943	0.2356	0.9098	0.2942

The influence of nutrition on FA structure in fat in pigs is documented in Table 3. In order to modify the FA content in the fat the linseed and corn were selected as

suitable additions to the regular diet, based mainly on the high content of PUFA in these components. Based on the addition of 15% linseed to the CFM there was a significantly lower (P≤0.01) content of SFA and MUFA detected and significantly higher (P≤0.01) portion of PUFA and total UFA detected in the fat. On the other hand, the addition of corn did not affect the representation of the FA groups with the exception of the total sum of MUFA (P≤0.05).

Table 3. The influence of nutrition on the fatty acid group in the backfat in pigs

FA	CON	C	L
SFA	47.78^{a}	47.74^{a}	42.72^{B}
MUFA	41.57^{a}	40.65^{b}	34.79^{C}
PUFA	10.62^{a}	11.56^{a}	22.46^{B}
UFA	52.19^{a}	52.21^{a}	57.25^{B}

CON - control group; C - group with the addition of corn; L - group with the addition of linseed
$^{a, b, c}$ Means within a row of equal groups with different letters are different for P≤0.05
$^{A, B, C}$ Means within a row of equal groups with different letters are different for P≤0.01

Table 4. The influence of gender on the fatty acid group in the backfat in pigs (% of total fatty acids)

Gender	SFA	MUFA	PUFA	UFA
Barrows	45.80a	38.19a	15.95A	54.15A
Gilts	44.68a	36.79b	18.51B	55.31B

$^{a, b, c}$ Means within a column of equal groups with different letters are different for P≤0.05
$^{A, B, C}$ Means within a column of equal groups with different letters are different for P≤0.01

The effect of nutrition, gender, carcass weight, lean meat proportion, intramuscular fat content and fatty acid groups in relation to oxidative stability was observed and evaluated. The results are documented in Table 5. Based on the results it is evident that the most significant influence was observed for the IMF content parameter as well as the corn addition. The least important influence affecting the carcass oxidative stability was found to be the LMP and the carcass weight. Similarly, the effect of FA groups on the oxidative stability was also evaluated. However, all of the observed relations were found not to be statistically significant (P>0.05).

Table 5. The statistical significance of the observed parameters on oxidative stability

Factor	Significance
Linseed	0.4154
Corn	0.2784
Sex	0.3643
Carcass weight	0.4612
Lean meat proportion	0.6658
Intramuscular fat	0.0741
SFA	0.5457
MUFA	0.4993
PUFA	0.5243

Discussion

There are a number of papers dealing with the influence of different fat sources in the diet on the carcass value in pigs. FA feed composition is reflected in the fat, especially in the backfat as well as the perirenal fat (Corino et al., 2002).

Among perspective crops suitable for their high PUFA content is corn. Although the content of linoleic acid, which is the most important PUFA representative, varies majorly between the modern corn hybrids, the average content reaches 59.7% of the total FA. This makes corn one of the most perspective PUFA sources (Della Casa et al., 2010).

However, meat products from pigs fed with a higher content of corn are in some markets classified as inferior when compared with the products from pigs fed with the usual commercial feeding mixtures based on barley and wheat. One of the reasons for this is the fact, that due to the higher UFA content in the corn seed the pig organism synthetizes softer fat which is more susceptible to fast oxidation. Studies published by Opapeju et al. (2006) and Della Cassy et al. (2010) showed a reduction of total SFAs and MUFAs and simultaneous increase of the total PUFA in pigs fed with the addition of corn.

Another important source of PUFA in the livestock feeding mixtures is the addition of linseed. However, similarly to the corn addition, products supplemented with linseed show a higher risk of decreased oxidative stability due to the high content of n-3 PUFA. Matthews et al. (2000) observed the effects of using 5 and 10% linseed addition in the diet of pigs. None of the experimental groups showed any negative effect of the feeding mixture on the oxidative stability of the meat. However Corino et al. (2002) worked with feeding mixtures enriched by corn oil and their study detected significantly higher TBARS leading to significantly lower oxidative stability when compared with the control group, despite the fact that the authors didn't detect any outstanding change in the FA composition.

Our study reached the significant changes in the FA composition with the use of feeding mixtures enriched by 15% linseed addition without observing any increased tendency toward oxidation. The results of the group with 12% corn addition correspond with the findings published by Corin et al. (2003). In this case the FA composition didn't show any significant changes, however the oxidative stability decreased markedly. Guo et al. (2006) reached the conclusion that the addition of corn doesn't influence the oxidative stability of fresh meat, although the same meat following heat treatment does show an increased tendency to undergo oxidation.

Guo et al. (2006) and Lahučký et al. (2005) point out the importance of antioxidants in the diet (vitamin E). Supplementing feeding mixtures with corn grain and vitamin E significantly increased the MUFA and UFA proportion, as well as the content of vitamin E in the meat. The meat oxidative stability, as indicated by the TBARS value, remained the same.

The effect of gender was demonstrated in the PUFA group. Haak et al. (2008), Warnans et al. (1999) state in their works, that the fat of fattened gilts shows a higher proportion of PUFA when compared with barrows, who show a higher ratio of SFA. Haak et al. (2008) also observed a significantly higher content of the main MUFAs in barrows fed with the addition of linseed or fish oil. A statistically significant effect on the MUFA and PUFA was also observed for the LMP parameter. A number of authors attribute the differences in the FA composition to breed, especially in relation

to different LMP in the carcass body of pigs. Raj et al. (2010); Wood et al. (2004); Kouba et Mourot (1999) report the effect of breed on the protein and fat concentration in the carcass to be very significant. This fact is then reflected in the FA composition in pigs. When compared with the usual hybrid combinations, there were higher PUFA concentrations (especially C18:2) detected in the pietrain breed, even though this breed is characteristic by higher protein and lower fat content in the carcass body. This finding points to the fact, that PUFA are more common in the fat of modern meat breeds than in the fat of pigs with a higher carcass fat content. Raj et al. (2010) explains that de novo synthesis of fatty acids is reduced in meat breeds (thus breeds with lower content of endogenous FA) resulting in lower dilution of exogenous acids synthesized by the saturated fatty acids. Although Warnants et al. (1999) reported that the effect of gender (barrows x gilts) influences the FA in IMF but doesn't bear any significant effect on the composition of FA in the backfat, our study found a higher amount of MUFA ($P \leq 0.05$) in barrows and higher amount of PUFA ($P \leq 0.01$) in gilts.

Conclusions

The results of this study were used in order to verify to which extend the monitored factors influence the FA composition. Concerning the manipulation with FA composition, the most suitable tool seems to be a steady diet with the supplement of linseed. The addition of linseed positively influences the FA composition while interacting with all of the FA groups. However the diet supplemented with corn as a source of PUFA proved to be ineffective. The study also showed that LMP represents not only a qualitative carcass body parameter, but also influences the FA composition of fat in pigs.

Regarding the influence of gender, the gilts showed a higher content of PUFA and SFA in the backfat. The study also monitored the oxidative stability of the backfat, however regarding this matter there were no statistically significant results. It can be concluded, that the FA composition is also affected by factors other than diet with high content of unsaturated fatty acids, even though the diet itself seems to be the most important factor concerning the manipulation with FA content in the fat of the pigs.

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