The influence of controlled nutrition intensity on the muscle fiber characteristics in fattening pigs

Vliv řízené intenzity výživy na charakteristiky svalových vláken u výkrmových prasat

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Abstract

The aim of this study was to evaluate the influence of controlled nutrition on the selected muscle fibres indicators and carcass value in pork. The test included 72 hybrid pigs of the D x (LW_D x L) genotype of a balanced sex (barrows/gilts). Animals were divided into two groups; the 1st (control) group was fed ad libitum, while the nutrition of the 2nd (experimental) group was restricted upon reaching 80 kg of live weight. The nutritional restriction was achieved by feeding the animals with maximum dose of CFM up to 2.8 kg*day^{-1} (corresponding to 36.4 MJ ME*day^{-1}, 46.76 g NS*day^{-1} and 23.52 g LYS*day^{-1}). From the obtained results it is evident that the daily feed intake restriction corresponds with greater number of the MLLT muscle fibers as well as with a higher IIB type muscle fibers share, higher lean meat share and a higher shoulder proportion in the carcass.

Keywords: carcass value, food technology, muscle fibre, pig

Abstrakt

Cílem práce bylo posoudit vliv řízené výživy na vybrané ukazatele svalových vláken a jatečné hodnoty vepřového masa. Test zahrnoval 72 prasat hybridní kombinace D x (LW_D x L) vyrovnaného pohlaví (vepříků/prasniček). Prasata byla rozdělena do dvou skupin, kontrolní skupina byla krmena ad libitum, experimentální skupina byla od 80 kg živé váhy restrigována. Restrikce spočívala v krmení nejvýše 2,8 kg KKS*den^{-1} (ME 36,40 MJ*den^{-1}, NL 46,76 g*den^{-1} a LYZ 23,52 g*den^{-1}). Ze získaných výsledků je patrný vliv restringované výživy na vyšší počet svalových vláken v MLLT, vyšší podíl svalových vláken typu IIB, vyšší podíl libové svaloviny a vyšší podíl plece z JUT.

Klíčová slova: jatečná hodnota, prase, svalové vlákno, technika krmení

Detailed abstract

Cílem práce bylo posoudit vliv řízené výživy na vybrané ukazatele svalových vláken a jatečné hodnoty vepřového masa. Test zahrnoval 72 prasat hybridní kombinace D x (LW_D x L) vyrovnaného pohlaví (vepříků/prasniček). Prasata byla rozdělena do dvou skupin, kontrolní skupina byla krmena ad libitum, experimentální skupina byla od 80 kg průměrné živé váhy do porážky v průměrné živé hmotnosti 115 kg restrigována. Restrikce spočívala v krmení nejvýše 2,8 kg KKS*den^{-1}, ME 36,40 MJ*den^{-1}, NL 46,76 g*den^{-1} a LYZ 23,52 g*den^{-1}. Kontrolní skupina v této fázi testu přijímala 3,13 kg KKS*den^{-1}, ME 40,69 MJ*den^{-1}, NL 52,27 g*den^{-1} a LYZ 26,29 g*den^{-1}, dokládá tabulka 1.
Vzorky svalové tkáně byly odebrány z pravých půlek jatečného trupu, z nejdelšího zádového svalu Musculus longissimus lumborum et thoracis (MLLT). Vzorky o velikosti 20x5x5 mm byly zmraženy pomocí tekutého dusíku a 2 – methylbutanu. Tloušťka řezu pro histologické zpracování byla nastavena 12 µm. Po fixaci preparátů v alkalické preinkubaci a jejich barvení, byly pořízeny fotografie svalových vláken a stanoveny jejich parametry a typologie, uvádí tabulka 2. U pravé poloviny JUT bylo stanoveno procento libové svaloviny přístojem FOM, změřena plocha svalu MLLT na příčném řezu, stanoven procentuelní podíl kýty (maso+kost), podíl plece (maso+kost) a podíl kotlety (maso+kost) z JUT, dokládá tabulka 3. Z výsledků je patrný vliv restringované výživy na vyšší počet svalových vláken v MLLT, vyšší podíl svalových vláken typu IIB, vyšší podíl libové svaloviny a vyšší podíl plece (maso+kost) z JUT. Jako statisticky nevýznamné se ukázaly diametr, perimetr svalových vláken a plocha svalu MLLT.

Introduction

The muscle fibres of the skeletal muscle are formed prenatally, while postnatal muscle growth mainly depends on progressive hypertrophy of the previously formed myofibrils. The metabolic differentiation of myofibrils occurs simultaneously with their growth, all during the postnatal period. At birth, the muscle composition is dominated by oxidative muscle fibers. With increasing age the metabolism changes as well and oxidative muscle fibers become progressively more glycolytic (Bee et al., 2007). The individual muscle fibre types are determined based on the type of their metabolism. Different sensitivity of the myofibrils to ATPase activity following previous exposure to either high or low pH values and subsequent coloring determines the three main types: I, IIA and IIB (Klont et al., 1998).

The change in individual muscle fiber types share is closely connected to the high growth intensity selection, which is reflected by higher proportion of white muscle fibers. These fibers are formed postnatally via the process of differentiation from the red muscle fibers (Hampl, 2007). The muscle area is determined by the muscle fibers characteristics, while muscle mass is determined by the number of muscle fibers. The number of muscle fibers is influenced mainly by both genetic and environmental factors, which are able to affect prenatal myogenesis.
The postnatal growth of skeletal muscles is realized by increasing both the muscle fibers length and perimeter (Rehfeldt et al., 2004).

The muscle fibers diameter is influenced by many internal factors, such as the genotype, sex and age (Bee et al., 2007; Gil et al., 2008). Another influencing element is represented by environmental factors, mainly physical activity and nutrition (Rehfeldt and Kuhn, 2006; Hampl, 2007). Nutrition, together with the animal's genotype, are considered to me the most important factors influencing the muscle fibers formation. The composition of muscle fibers is closely related to the final pork meat quality and its variability with relation to intramuscular fat content interaction (Čandek-Potokar et al., 1999; Kristensen et al., 2002; Gil et al., 2008). In this context, lowered fat content is a result of inadequate nutritient amount in the diet (Lebret, 2008, Blacquière et al., 2012, Skiba et al., 2012). As stated by Maltin et al. (2003), when animals are fed ad libitum the resulting meat is softer than in animals, whose nutrition was subject to restriction. They also found a correlation between the growth intensity, meat tenderness and the nutrition intensity. The results show that the food intake modification during growth period can significantly change the nutritional value and quality of pork meat, especially its tenderness (Wiecek et al., 2011).

The increase in meat tenderness is achieved by feeding the animals ad libitum following the previous dietary restrictions. This way there is a markedly higher protein production (especially in gilts), leading to changes in the carcass composition and in protein storage (Kristensen et al., 2004, Therkildsen et al., 2004; Nowachowicz et al., 2009). The qualitative and quantitative aspects of postnatal nutrition have a major effect on the muscles development, affecting the growth rate and body composition (Bee et al., 2007). It is evident, that implementation of various feeding techniques (thus supplying the animals with variable nutrient amount in one dose, particularly concerning the energy and proteins) can lead to a different nutritional composition of the carcass (Gil et al., 2008). These changes are then reflected in the muscle fibers typology (Maltin et al., 2003) and the carcass value (Maltin et al., 2003; Stupka et al., 2009; Wiecek et al., 2011).

The aim of this study was to evaluate the influence of the controlled nutrition on the selected muscle fibres indicators and on the carcass value in pork meat.

Material and methods

The test included 72 hybrid pigs of the D x (LW_D x L) genotype. Same-sex pigs were penned in pairs. The representation of both sexes in each group was 1:1. The animals included in the test weighed 17 - 115 kg (slaugther weight) of an average live weight (ALW).

The observed animals were divided into two groups, based on their nutrition level. The first (control) group was fed ad libitum during the whole duration of the study, while the animals in the second (experimental) group were fed with restricted amount of nutrition upon reaching 80 kg of an average live weight (third phase of the study). The animals in the experimental group were fed with a diet of up to 2.8 kg*day^{-1} for both sexes, with the nutrient intake not exceeding 36.40 MJ ME*day^{-1}, 46.76 g*day^{-1} of protein and 23.52 g*day^{-1} of lysine. The overall composition of the diet (CFM), nutritional content and analysis of animal daily feed intake (DFI) and nutrient intake (DNI), with regards to the specific test phases, is documented in Table 1.

The fattening phases of the study were as follows: 1st (from the beginning of the test up to the average body weight of 39.9 kg), 2nd (from 40 to 79.9 kg) and 3rd (from 80 kg up to the slaugher weight).

Following the slaughter, 60 right halves were dissected and used in order to obtain muscle samples from the MLLT (musculus longissimus lumborum et thoracis).

All samples (size 20x5x5mm) were frozen with the use of liquid nitrogen and 2-methylbutane. Leica microtome CM 1850 was used in order to prepare thin histological slides. Optimum width of the individual slides was chosen to be 12 μm. Following the fixation in alkaline preincubation and staining, the muscle fibers were examined and photographed with the use of Nikon Eclipse E200 microscope with Nikon DS-Fil camera. At this point the muscle fibers parameters and typologies could be determined. The lean meat share (LMP) was determined with the use of FOM equipment (Pulkrábek et al., 2006) for the right half carcass.

Based on the photos obtained from the EOS 550 D camera with the Canon EFS 18-135 mm lens, the loin eye area (MLLT) behind the last thoracic vertebra was measured at the same half carcass (Čítek et al., 2009).

Another obtained and determined values include the percentage of the ham (meat+bone), shoulder (meat+bone) and loin (meat+bone) of the carcass.

The data evaluation was performed with the help of the NIS-Elements AR software for image analysis (version 3.2) and the SAS statistical program, version 9.1.

Results and discussion

Table 1. The CFM component composition, nutrient contents and daily animal nutrient intake with respect to the current feeding phase

Tabulka 1. Komponentní složení krmné dávky s analýzou obsahu živin a příjmem živin zvířaty dle fáze testu

Item / Ingredients	Control group			Experimental group		
	Phase					
	1 (17-40kg)	2 (40-80kg)	3 (80-115kg)	1 (17-40kg)	2 (40-80kg)	3 (80-115kg)
Wheat (%)	49.3	49.4	49.9	49.3	49.4	49.9
Barley (%)	23.0	30.0	35.0	23.0	30.0	35.0
Soybean (%)	22.7	15.6	10.1	22.7	15.6	10.1
Premix (%)	5.0	5.0	5.0	5.0	5.0	5.0
Analyzed nutrient composition						
ME (MJ*kg^{-1})	13.20	13.10	13.00	13.20	13.10	13.00
NL (g*kg^{-1})	19.60	18.75	16.70	19.60	18.75	16.70
LYS (g*kg^{-1})	12.20	10.40	8.40	12.20	10.40	8.40
Dry matter (g*kg^{-1})	909.68	910.52	911.17	909.68	910.52	911.17
Crude fiber (g*kg^{-1})	25.45	25.08	24.79	25.45	25.08	24.79
DFI and DNI						
DFI (kg*day^{-1})	1.49	2.52	3.13	1.54	2.51	2.80
ME (MJ*day^{-1})	19.67	33.01	40.69	20.33	32.88	36.40
NL (g*day^{-1})	29.20	47.25	52.27	30.18	47.06	46.76
LYS (g*day^{-1})	18.18	26.21	26.29	18.79	26.10	23.52
Dry matter (g*day^{-1})	1355.43	2294.50	2851.96	1400.91	2285.40	2551.27
Crude fiber (g*day^{-1})	37.92	63.20	77.60	39.19	62.95	69.42

The test results documented Table 2.

Table 2. Selected indicators of the muscle fibers in relation to different nutrition levels

Tabulka 2. Vybrané ukazatele svalových vláken ve vztahu k rozdílné úrovni výživy

Item / Nutrition		Ad libitum	Restriction	P
Muscle fibers	Number	88,00±19,08	91,13±21,12	≤0,001
	Diameter (µm)	71,24±0,44	70,99±0,51	NS
	Perimeter (µm)	256,42±2,01	266,69±2,30	NS
	Circularity	0,75±0,003	0,73±0,003	≤0,001
Muscle fibers proportion - type	I (%)	10,08±0,11	9,10±0,13	≤0,001
	IIA (%)	4,53±0,11	2,55±0,12	≤0,001
	IIB (%)	85,39±015	88,36±0,17	≤0,001

Similarly, the muscle fibers perimeter displayed insignificant differences between the pigs that were fed ad libitum and pigs with restricted nutrition. However, Bee et al. (2006) states, that the restriction had an impact on reduced muscle fibers perimeter.

As is further evident, a significant effect of nutrition on the muscle fibers number (P<0.001) has been demonstrated. The experimental group had a higher number of muscle fibers (91.13±21.12), as compared to the pigs fed ad libitum (88.00±19.08). The effect of nutrition on muscle fibers circularity was another value that showed statistically significant results between the two groups. The conrol group reached a significantly higher circularity at a rate of 0.02.

The ad libitum group showed a significantly higher proportion of the muscle fibers type I (10.08±0.11 %) and IIA (4.53±0.11 %), with lower share of muscle fibers type IIB (85.39±0.15 %). The animals with restricted nutrition displayed a significantly (P<0.001) higher muscle fibers IIB share (88.36±0.17 %) and lower muscle fibers proportions of the type I (9.10±0.13 %) and IIA (2.55±0.12 %). However, these findings are not in accordance with those published by Fraga et al. (2009), who states that the nutritional restrictions do not affect the share of individual muscle fibers. Cerisuel et al. (2009) argues, that the number of muscle fibers is determined prenatally and as such is influenced by the sow nutrition levels.

The following Table 3 shows the differences between the groups concerning selected indicators of carcass value with respect to nutrition.

Table 3. Indicators of the carcass value in relation to different nutrition levels

Tabulka 3. Ukazatele jatečné hodnoty ve vztahu k rozdílnému řízení úrovně výživy

Item / Nutrition		Ad libitum	Restriction	P
Loin eye area (mm^2)		4353±51,09	4347±58,27	NS
ALW (kg)		112±10,32	106±9,20	NS
LMP (%)		55,98±0,03	56,10±0,04	≤0,05
Proportion of the	ham	22,02±0,03	21,67±0,04	≤0,001
	shoulder	10,94±0,01	11,08±0,01	≤0,001
	loin	12,56±0,02	12,50±0,02	≤0,05

As it is evident, this table showed no significant differences between the groups for the loin eye area of the MLLT. However, the MLLT area seemed to reach higher values in the animals fed ad libitum. This finding is supported by Critser et al. (1995), who also report that the ad libitum fed animals displayed larger MLLT area. The same conclusion was reached by Fabian et al. (2002), despite the fact that their results were found to be more evidential. Different findings were published by Bee et al. (2007), who observed larger MLLT area in the experimental groups (animals with restricted nutrition).

The differences between average slaugher weight showed to be statistically insignificant, with the ad libitum fed pigs displaying an inclination to reach higher average slaughter weight. Bee at al. (2007) support this finding, which in their study reached statistically significant values ($P<0.01$). Although the experimental group showed lower ALW, the same group reached a significantly ($P<0.05$) higher proportion of LMP (by 0.12 %). This finding is fully in accordance with the works of Bee at al. (2007) and Serrano et al. (2009). Reynolds and O'Doherty (2006) reached the same conclusions and also reported that the LMP is a function of the lysine amount intake.

Concerning the main meaty parts of the carcass, the above table clearly shows that the ham share (or loin) was demonstrably ($P<0.001$, $P<0.05$) higher in the control group (pigs fed ad libitum) – by 0.35 (or 0.06 %). An opposite relationship was shown for the shoulder values, where the ad libitum feeding was associated with lower shoulder share in the carcass, as documented by the work of Bee et al. (2007).

Conclusion

From the results it is evident that different levels of nutrition affect important indicators of the muscle fibers and carcass characteristics. Concerning this conclusion it is documented, that a restricted feeding leads to a greater number of muscle fibers and a higher fast glycolytic muscle fibers type IIB proportion.

Limited nutrition (as compared to the pigs fed ad libitum) also resulted in a statistically significant differences in the higher LMP and higher shoulder proportions. On the other hand, the ad libitum feeding leads to a higher ham and loin share in the pig carcass.

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