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Profile of fatty acids, muscle structure and shear force of musculus *longissimus dorsi* (MLD) in growing pigs as affected by energy and protein or protein restriction followed by realimentation

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ABSTRACT

Forty-eight gilts were submitted to a 30% restriction of feed (groups F and F1) or protein intake (group P) from 90 to 118 days of age, followed by realimentation from 119 to 168 days of age. Control pigs (C) were fed during the whole experiment according to a *semi ad libitum* scale. During realimentation all animals were fed according to semi *ad libitum* scale except pigs F1 which were fed *ad libitum*. Six pigs from each group were slaughtered at the end of restriction and realimentation. Restriction decreased the weight of musculus *longissimus dorsi* (MLD) and increased shear force. Restriction of feed intake depressed MUFA concentration and increased n-6/n-3 ratio while protein restriction decreased n-6/n-3 and PUFA:SFA ratios. Structure of fibers was not affected. After realimentation MLD mass was still lower in all previously restricted pigs, shear force was the lowest in F1 pigs. Only percentage of fast twich oxidative fibers was significantly greater in F1 pigs than in others. Significant correlations between parameters investigated during the study were found.

1. Introduction

Nutrition is one of many factors which affect quality of pork. Many authors reported that level of nutrition can influence intramuscular fat content (Masson et al., 2005; Skiba, 2010; Więcek, Rekiel, & Skomiał, 2010), while recent studies of Stolzenbach et al. (2009) showed that feeding strategy including compensatory growth can improve also meat tenderness/shear force. A positive effect of compensatory growth on shear force of meat during few weeks of realimentation was also reported by Skiba (2010) but other authors did not find such effect (Heyer & Lebret, 2007).

Feeding intensity and strategy of compensatory growth influence amount of fat deposited in the body (Skiba, Fandrejewski, Raj, & Weremko, 2005) and also its fatty acid profile (Więcek, Rekiel, Batorska, & Skomiał, 2011), mainly due to the changes of activity of lipogenic enzymes (Daza et al., 2007). The results are, however, often inconsistent because of differences in genetic origin of pigs and experimental design as well.

Some authors postulate that there are relationships between fatty acid profile and type of fibers in the muscle (Andres et al., 2001). It seems therefore, that modification of muscle structure can affect meat quality but in the studies on the morphology of the muscle the relationships between these traits and parameters of pork quality were not analyzed. Moreover, the muscle structure was usually determined only at one stage of growth, prevalently at slaughter weight.

The objective of the present experiment was to determine the effect of different strategies of pig nutrition (restriction and realimentation) on intramuscular fat content and fatty acids profile, shear force and structure of the *musculus longissimus dorsi*, and to estimate possible interrelationships between these parameters. The pigs were subjected to the restriction of energy and protein or only protein intake in the early growth stage (91st to 118th day of life) followed by realimentation till slaughter weight at the age of 168 days. The compensatory growth was induced to diversify amount and composition of fat deposited in the muscle without supplementation of the diet with fat. It was assumed that different intake of energy and protein in early growth of pigs will change characteristic of the *musculus longissimus dorsi* and that these changes will be maintained till heavier body mass.

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2. Materials and methods

2.1. Animals, diets and experimental procedures

The experimental procedures were approved by the Local Ethical Commission. The experiment was performed on 54 gilts, progeny of a Danish Landrace boar and seven half-sisters Large White sows. At the age of 90 days the animals were allotted to four experimental groups of 12 gilts, and one additional "zero" group of 6 gilts, two or three pigs from each litter being assigned to the treatment to minimize genetic variability. Two diets were formulated: diet A and diet P containing about 70% less protein than diet A (Table 1). The experiment comprised a restriction period from 91st to 118th day of life and a realimentation period from 119th to 168th day of life. Control animals (group C) were fed during both periods on diet A according to a *semi ad libitum* scale (approximately 95% of *ad libitum* intake). During the restriction period two groups of animals (F and F1) were fed diet A at the feeding level of approximately 70% of feed intake in group C, and one group (P) was fed on a low-protein P diet to consume 70% less of protein only. During the realimentation period all groups were fed on diet A at the *semi ad libitum* scale (approximately 95% of *ad libitum* intake), except F1 group which was fed *ad libitum*. The scheme of the study is presented in Table 2. The aim of the application a *semi ad libitum* scale in feeding of pigs was to fully control a nutrient intake during restriction. Such kind of feeding during realimentation allowed pigs to exhibit a "clear" compensation (without influence of feed intake). According to results of earlier studies when pigs are re-alimented *ad libitum* (e.g. Bikker, 1994; De Greef, 1992) these previously restricted with feed (protein and energy) intake show a higher appetite. Contrary, those previously restricted with protein intake only characterize feed intake similar to control animals. Thus, to measure an influence of voluntary feed intake on investigated parameters during realimentation period the *ad libitum* feeding of F1 pigs was used.

Animal age plays a crucial role in the processes of both "normal" and compensatory growth (Hogg, 1991; Lawrence & Flower, 2002). For this reason scheme of the experiment assumed comparison of pigs at similar age (not body weight), thus body weight and other investigated features was only result of applied feeding procedure. The animals were maintained individually in pens equipped with automatic feeders and nipple drinkers, in thermally neutral environment. Feed allowances for pigs were changed every week adjusted to experimental protocol, except pigs of F1 group during realimentration when they were fed *ad libitum*. *Semi ad libitum* intake of control pigs during each week/period of the experiment was assumed based on *ad libitum* intake of this genotype of pigs recorded in our earlier studies (unpublished data). On the base of this intake a restriction level for F and F1 pigs were calculated to these animals consumed 70% of feed (lysine and ME) in group C. Due to a higher energy content in the diet P daily allowance during following week of the restriction for these animals was adjusted to they consumed daily the same amount of energy, but only 70% of protein as C pigs. The average quantities of feed and daily intake of apparent ileal digestible lysine and metabolisable energy, allowed per pig are presented in Table 3.

At the age of 90 days six pigs from "zero" group were slaughtered by exsanguination after electrical stunning. Six gilts from each group were slaughtered at the end of restriction period and six at the end of realimentation, at the age of 118 and 168 days, respectively. Immediately after slaughter carcass was weighted afterwards halved, and samples of the *musculus longissimus dorsi* (MLD) from the last rib area of the right half of the carcass were taken for histological analysis and stored at − 20 °C. The carcasses were chilled at 4 °C for 24 h. Then, at the left half-carcass of each pigs a backfat thickness was measured at 5 points (above: neck, last rib, and *musculus gluteus* at three points — front, middle and hind). From these measurements an average value was calculated. Next, the entire MLD was dissected from the left half of the carcass and weighed. Meat content in the carcass of pigs at 118 and 168 days of life was calculated according to formula

Table 1
Composition and profile of fatty acids of experimental diets.

Ingredients	Diet		Profile of fatty acids, %	Diet	
	A	P		A	P
Barley, g/kg	250	310	C14:0	0.21	0.33
Wheat, g/kg	245	200	C16:0	24.77	28.94
Triticale, g/kg	90	90	C18:0	3.84	4.25
Maize, g/kg	200	–	Σ SFA	32.78	37.27
Soybean meal, g/kg	160	100	C16:1n-7	0.3	0.3
Rapeseed meal, g/kg	30	–	C18:1n-9	34.08	26.20
Premix[a], g/kg	25	25	C18:1n-7	2.09	1.71
Cereal starch, g/kg	–	275	Σ MUFA	37.92	30.05
Chemical composition	C18:2n-6	25.25	27.39		
Dry matter, g/kg	874.4	888.7	C18:3n-6	0	0.04
Crude protein, g/kg	167.5	112.3	C18:3n-3	1.36	1.65
Fat (extract ether), g/kg	26.4	16.5	C20:3n-6	0	0
Ash, g/kg	43.0	43.5	C20:4n-6	0.52	0.68
Nitrogen free extract, g/kg	602.1	685.8	C20:5n-3	0	0
Crude fiber, g/kg	35.4	30.6	C22:5n-3	0.07	0.06
ADF, g/kg	52.5	42.9	C22:6n-3	0	0
NDF, g/kg	135.8	107.8	Σ PUFA	27.41	30.07
ADL, g/kg	10.9	8.6	PUFA/SFA	0.84	0.8
Starch, g/kg	461.0	572.8	C18:2n-6/ C18:3n-3	18.57	16.60
Sugar, g/kg	36.1	24.7	Σ n-6/Σn-3	17.65	15.88
Organic matter, g/kg	831.4	845.2			
Lysine[b], g/kg	8.26	5.72			
Methionine[b], g/kg	2.41	1.68			
Threonine[b], g/kg	4.74	3.30			
Tryptophan[b], g/kg	1.59	1.10			
Metabolisable energy, MJ/kg	12.86	13.63			

[a] Premix contained per kg (Diet A, values in parentheses refer to Diet P): 211.9 (232.9) g Ca; 34.52(46.46) g P; 45.46 (51.40) g Na; 2.46 (2.46) g Fe; 3.29 (3.29) g Zn; 1.03 (1.03) g Cu; 1.23 (1.23) g Mn; 12.3 (12.3) g I; 8.2 (8.2) g Se; 206,000 (206,000) IU vitamin A; 25,000 (25,000) IU vitamin D3; 1650 (1650) mg vitamin E; 2.46 (2.46) mg vitamin K; 82.3 (82.3) mg vitamin B1; 820 (820) mg vitamin B2; 0.82 (0.82) mg vitamin B12; 0.006 (0.006) mg biotin; 0.053 (0.053) mg folic acid; 620.7 (620.7) mg nicotinic acid; 410.9 (410.9) mg calcium pantothenate; 40.8 (40.8) mg choline chloride; 87.0 (69.0) g lysine; 7.84 (10.68) g methionine; 13.46 (17.23) g threonine; 5.54 (3.96) g tryptophan.
[b] Apparent ileal digestible according to the CVB (1995).

Table 2
Scheme of the experiment.

Growth stage	Daily intake of energy/protein as a percent of intake of control group			
	C[a]	P	F	F1
Restriction (90–118 days of life)	100/100	100/70	70/70	70/70
Realimentation (119–168 days of life)	100/100	100/100	100/100	*Ad libitum*

[a] 95% of *ad libitum* intake.

Table 3
Diets fed during the experiment and average daily intake of feed, apparent ileal digestible lysine (Lys) and metabolisable energy (ME) in the experimental groups.

Experimental period	Age (day)		Group			
			C	P	F	F1
Restriction	90–118	Diet	A	P	A	A
		kg/day	2.13	2.00	1.50	1.50
		Lys, g/day	17.6	12.3	12.3	12.3
		ME, MJ/day	27.3	27.3	19.1	19.1
Realimentation	119–168	Diet	A	A	A	A
		kg/day	2.70	2.70	2..70	*Ad libitum* (2.85)
		Lys, g/day	22.3	22.3	22.3	23.5
		ME, MJ/day	34.7	34.7	34.7	36.6