Effect of weight and sex on intramuscular fat amounts in relation to the formation of selected carcass cuts in pigs

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ABSTRACT: The objective of this study was to examine the influence of weight and sex on fat amounts in relation to the formation of selected carcass cuts in final hybrid pigs commonly kept in the Czech Republic. During the experiment 123 hybrid pigs of various genotypes were tested. The pigs were slaughtered at an average weight of 120.4 kg and dissected in detail. The tested pigs were divided into 5 weight categories, while the tissue composition of ham, joint, shoulder and neck was monitored with emphasis on the assessment of IMF content. A decrease in the lean meat proportion was shown, as well as an increasing fat proportion with increasing weight: for the joint the difference was 4.19%, for the ham 3.9%, shoulder 3.0%, and neck 2.31%. With increasing weight, a moderate increase in intramuscular fat occurred, whereas the differences between group 1 and 5 were: 1.68% for the ham, 0.58% (shoulder), 0.4% (joint) and 0.37% (neck). Concerning the influence of sex, barrows had statistically insignificant intramuscular fat content compared with gilts (excluding the neck). As for the protein content in the monitored carcass cuts, no influence of live weight and sex was recorded.

Keywords: pig; meat; intramuscular fat; live weight; sex

Pork represents one of the most popular foodstuffs because of its taste and nutritional value. It is an important component of daily diet. In terms of nutrition it is regarded as a very rich source of proteins, vitamins, unsaturated fatty acids and mineral compounds.

With increasing slaughter weight (SW), the carcass value (CV) concerning the meat/fat ratio in half-carcasses deteriorates (Pulkrábek et al., 1999). The absolute lean meat proportion increases, and the relative one decreases. As for the proportion of fat in the carcass, the absolute and relative values increase.

Willam et al. (1990) considered SW as the most important factor, affecting both the quantitative and qualitative aspects of CV. On the contrary, Bruwe et al. (1991) mentioned all aspects of CV as substantially affected by sex.

Monitoring the content and composition of intramuscular fat (as a part of lean meat) is increasingly important. It is difficult to distinguish between the lipids of cell membranes (mainly phospholipids) with constant ratios (0.6–0.8%) and the fat deposit (triacylglycerols) in adipose cells of the perimysium, the content of which varies.

It is possible to detect decreased intramuscular fat in modern breeds and highly meaty final hybrids worldwide. In recent years, the meatiness of final hybrids and their growth intensity have increased while the intramuscular fat (IMF) amounts in monitored carcass parts have decreased.

The IMF level is often reported to have beneficial effects on the nutritional quality of pork (Bejerholm and Barton-Gade, 1986; Wood, 1990; Stoier et al., 1998; Fernandez et al., 1999; Brewer et

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al., 2001; Wood et al., 2004) although some authors have shown only a weak influence (Eikelenboom et al., 1996) or even no influence (Göransson et al., 1992).

The IMF content represents the criterion of the physiological status of animal. Brewer et al. (1999) reported that the optimum fat amount in MLLT (SW = 100 kg) was 25 g/kg. Consumers regard lean meat with more than 40 g/kg as too fatty; the most preferred values are 25–35 g/kg (deVole et al., 1988; Verbeke et al., 1999). The minimum IMF should exceed 15 g/kg. Besides other factors, IMF is important for consumers from the aspect of the taste qualities of meat, the most significant being its tenderness and juiciness.

In pig carcasses there are significant topographic differences in IMF distribution. According to Fischer (2001), the lowest IMF values (1.1–1.4%) were observed in the muscles *m. rectus femoris*, *m. adductor*, *m. psoas major* and *m. longissimus lumborum*. Medium IMF values (1.7–2.7%) are represented by some muscles of the shoulder (*m. triceps brachii*, *m. supraspinatus*, *m. infraspinatus*) and the ham (*m. semimembranosus*, *m. biceps femoris*). There are increased amounts of IMF in some muscles of the neck (*m. serratus ventralis*, *m. semispinalis capitis*).

Some authors stated that the IMF content mainly depends on the genetic influence of parents, but sex (barrows and gilts) also has its influence, as well as the carcass weight and applied nutrition (Cameron et al., 1990; Gonzalez et al., 2001; Brewer et al., 2002; Tibau et al., 2002) whereas others disagree (Hamilton et al., 2000; Faucitano et al., 2004).

After the evaluation of differences between barrows and gilts, an average difference of 7.7 g/kg was observed in about 400 pigs of 85–135 kg slaughter categories. The least difference (6.4 g/kg) between the two sexes was in the category of 90–100 kg. This difference increased in both lighter and heavier categories. This fact was more obvious in barrows (a range of 25.8–40.1 g/kg) than in gilts (18.7 to 22.4 g/kg). The influence of sex is recognized when barrows show a higher content of IMF and intermuscular or subcutaneous fat than gilts (Okrouhlá et al., 2006).

The objective of this paper is to evaluate the influence of live weight and sex (barrows versus gilts) on IMF content in relation to the formation of selected carcass cuts in final hybrids of pigs kept in the Czech Republic.

MATERIAL AND METHODS

During the experiment 123 hybrid pigs of three genotypes were tested. Czech Large White × Czech Landrace breeds were used as dams, and Pietrain (n = 41), Pietrain × Hampshire (n = 41) and PIC hybrid boars (n = 41) as sires. All the pigs were 68 days old and weighed 25.0 kg. The experiment lasted for 103 days.

In order to estimate the influence of weight on the monitored indexes in selected carcass parts, the animals were divided into five weight groups which are shown in Table 1.

Further, an evaluation of the influence of sex on the monitored selected carcass parts was performed, when all pigs were divided into barrows (1) and gilts (2).

The pigs were penned in pairs (barrow/gilt) at the test station of the Department of Animal Husbandry, Czech University of Life Sciences in accordance with the methods for testing pure-bred and hybrid pigs (Smolák and Ivánek, 1992). The pigs were fattened on four-component complete feed mixtures (CFM) with wheat, barley, extracted soya meal and premix using Duräumat self-feeders with continual alternation. The CFMs were mixed for each pen according to particularly specified feeding curves. Before the start of the experiment, analyses of particular CFM components were examined with regard to the main nutrients. Based on these analyses, feed mixtures and their composi-

Table 1. Division of the tested pigs into weight groups according to their weights

Groups	n	Minimum	Maximum	Mean	SE
1	8	97.20	104.50	100.85	0.78
2	23	105.00	114.50	110.98	0.58
3	51	115.00	124.50	119.72	0.43
4	32	125.00	134.00	128.13	0.43
5	9	135.00	144.00	138.44	1.04

Table 2. Feeding scheme

Nutrients in FCM	Feeding phase		
	> 35 kg	35–65 kg	< 65 kg
Crude protein (g/kg)	196.70	184.00	156.30
ME (MJ/kg)	13.30	13.20	12.90
Crude fibre (g/kg)	39.84	38.76	40.75
Lysine (g/kg)	11.40	10.20	8.30
Threonine (g/kg)	7.20	6.50	5.40
Methionine (g/kg)	3.20	2.90	2.40
Ca (g/kg)	7.20	6.80	6.10
P (g/kg)	5.50	5.40	4.60

tions (related to the age and weight of tested pigs) were formulated (Table 2).

The dietary consumption was estimated for pairs (one pen) and then divided among individual pigs. Before testing, weaners were fattened on a common feeding mixture (designed for pigs in a pre-feeding period) at their home farm.

During the experiment, the microclimate of the test-station pens was monitored and controlled in accordance with values defined in advance.

The pigs were slaughtered at average live weight of 120.4 kg at 171 days of age. The following day a detailed carcass dissection was performed in accordance with Walstra and Merkus (1996), while the methodology was expanded in the neck area. Only the major meat cuts of the carcasses which are used in the Czech Republic were included in the monitoring.

For the four main meat cuts (ham, joint, shoulder and neck) the following indexes were determined:

– total weight (kg);
– meat weight (kg);
– lean meat ratio (%);
– weight of subcutaneous fat (kg);
– ratio of subcutaneous fat (%);
– intramuscular fat IMF (%);
– protein (%).

The lean meat proportion of pig carcasses (%) was also monitored using the Fat-O-Meater formula (Pulkrábek et al., 2004).

IMF was assessed in the laboratory by gravimetry after petroleum-ether extraction. Protein was assessed in the laboratory in accordance with standard ČSN ISO 937 (2002).

Basic parameters of fattening capacity in the monitored groups are given in Table 3.

The dataset was analysed using ANOVA by the statistical program SAS 9.1.3, GLM (SAS, 2001). The following linear regression model was used to estimate the effects of body weight:

$$Y_{ijk} = \mu + CW_i + \mathrm{Sex}_j + \mathrm{Gen}_k + e_{ijk}$$

where:

Y_{ijk} = observed value of the carcass parameter as a dependent variable
μ = average value of dependent variable
CW_i = fixed effect of live weight
Sex_j = fixed effect of sex
Gen_k = fixed effect of genotype
e_{ijk} = residual effects (random error)

RESULTS AND DISCUSSION

Table 4 shows basic statistical values characterizing the influence of live weight on IMF content and carcass value traits in the selected carcass parts. Evaluating this influence on the formation of particular selected carcass parts, we can state that with increasing weight the total weight, meat weight and subcutaneous fat weight of all parts increase in accordance with Pulkrábek et al. (2006). Concerning the ratio of the monitored traits, it is clear that

Table 3. Characteristics of selected traits of fattening capacity (entire set)

	Total		Barrows		Gilts	
	mean	s	mean	s	mean	s
ADG (g/day)	921	101	949	99	865	81
ALMG (g/day)	556	55	541	53	585	46
Lean meat proportion (%)	55.6	5.5	54.1	5.3	58.5	4.6

ADG = average daily gain; ALMG = average lean meat gain

Table 4. Influence of live weight on IMF and carcass value in selected pig carcass cuts

Group	1		2		3		4		5		*F*-value	Alfa
	LSMEAN	SE	LSMEAN	SE	LSMEAN	SE	LSMEAN	SE	LSMEAN	SE		
Ham weight and composition												
Total weight (kg)	11.08	0.30	12.34	0.17	13.02	0.12	14.02	0.16	15.16	0.27	36.83	<.00010
Weight of lean meat (kg)	8.94	0.30	10.01	0.17	10.36	0.12	10.99	0.16	11.62	0.28	14.46	<.00010
Lean meat proportion (%)	80.51	1.18	81.06	0.67	79.54	0.46	78.32	0.63	76.57	1.08	3.97	0.0047
Subcutaneous fat weight (kg)	2.14	0.16	2.33	0.09	2.65	0.06	3.03	0.08	3.54	0.14	19.19	<.00010
Subcutaneous fat proportion (%)	19.49	1.18	18.94	0.67	20.46	0.46	21.68	0.63	23.43	1.08	3.97	0.0047
IMF (%)	2.43	0.58	3.42	0.34	3.30	0.24	3.55	0.35	4.67	0.69	1.96	0.1700
Protein (%)	22.45	0.34	22.06	0.19	22.33	0.13	22.25	0.18	21.83	0.31	0.89	0.4697
Shoulder weight and composition												
Total weight (kg)	5.32	0.14	5.93	0.08	6.34	0.05	6.87	0.07	6.93	0.12	36.64	<.00010
Weight of lean meat (kg)	3.97	0.14	4.49	0.08	4.69	0.05	4.93	0.07	4.99	0.13	11.35	<.00010
Lean meat proportion (%)	74.73	1.48	75.68	0.84	74.01	0.58	71.90	0.79	71.73	1.35	3.24	0.0147
Subcutaneous fat weight (kg)	1.34	0.10	1.44	0.06	1.64	0.04	1.93	0.05	1.94	0.09	14.59	<.00010
Subcutaneous fat proportion (%)	25.27	1.48	24.32	0.84	25.99	0.58	28.10	0.79	28.27	1.35	3.24	0.0147
IMF (%)	1.75	0.32	2.69	0.17	2.57	0.11	2.60	0.15	2.71	0.27	1.81	0.1312
Protein (%)	20.55	0.29	20.82	0.17	21.05	0.11	20.99	0.15	20.79	0.26	0.91	0.4598
Neck weight and composition												
Total weight (kg)	3.35	0.13	3.50	0.07	3.78	0.05	4.03	0.07	4.50	0.12	17.65	<.00010
Weight of lean meat (kg)	2.84	0.11	2.95	0.06	3.20	0.04	3.40	0.06	3.71	0.10	16.07	<.00010
Lean meat proportion (%)	85.25	1.09	84.50	0.62	84.70	0.43	84.78	0.59	82.94	1.00	0.84	0.4995
Subcutaneous fat weight (kg)	0.50	0.05	0.55	0.03	0.58	0.02	0.62	0.03	0.79	0.05	5.21	0.0007
Subcutaneous fat proportion (%)	14.75	1.09	15.50	0.62	15.30	0.43	15.22	0.59	17.06	1.00	0.84	0.4995
IMF (%)	5.57	0.84	6.17	0.48	6.26	0.29	6.44	0.42	7.22	0.71	0.65	0.6295
Protein (%)	20.81	0.35	20.96	0.21	20.46	0.14	20.73	0.19	20.51	0.32	1.21	0.3101
Joint weight and composition												
Total weight (kg)	7.25	0.26	8.22	0.15	8.95	0.10	9.76	0.14	10.45	0.24	32.07	<.00010
Weight of lean meat (kg)	5.23	0.21	5.93	0.12	6.30	0.08	6.73	0.11	7.10	0.19	15.46	<.00010
Lean meat proportion (%)	72.63	1.58	72.36	0.90	70.43	0.62	69.30	0.85	68.44	1.45	2.30	0.0634
Subcutaneous fat weight (kg)	2.01	0.18	2.29	0.10	2.66	0.07	3.02	0.10	3.35	0.16	13.54	<.00010
Subcutaneous fat proportion (%)	27.37	1.58	27.64	0.90	29.57	0.62	30.70	0.85	31.56	1.45	2.30	0.0634
IMF (%)	1.13	0,23	1.63	0.10	1.51	0.07	1.79	0.10	1.88	0.17	3.17	0.0167
Protein (%)	23.81	0.63	23.87	0.37	23.56	0.25	23.71	0.34	23.57	0.58	2.28	0.0651

Table 5. Estimation of regression and correlation coefficients of selected traits and live weight

Parameter	Intercept	Parameters of live weight	R^2	Correlation coefficients	Alfa
Ham weight and composition					
Total weight (kg)	2.71190	0.0866	0.33	0.574	<.0001
Weight of lean meat (kg)	4.32980	0.0503	0.16	0.395	<.0001
Lean meat proportion (%)	95.67670	−0.1381	0.14	−0.371	<.0001
Subcutaneous fat weight (kg)	−1.61790	0.0363	0.38	0.615	<.0001
Subcutaneous fat proportion (%)	4.32330	0.1381	0.14	0.371	<.0001
IMF (%)	0.94715	0.0202	0.01	0.131	0.255
Protein (%)	22.39970	−0.0014	0.00	−0.015	0.8712
Shoulder weight and composition					
Total weight (kg)	1.63230	0.0393	0.430	0.654	<.0001
Weight of lean meat (kg)	2.58830	0.0173	0.120	0.346	<.0001
Lean meat proportion (%)	96.18130	−0.1895	0.160	−0.394	<.0001
Subcutaneous fat weight (kg)	−0.95600	0.0221	0.380	0.619	<.0001
Subcutaneous fat proportion (%)	3.81870	0.1895	0.160	0.394	<.0001
IMF (%)	3.54000	−0.0082	0.004	−0.067	0.4720
Protein (%)	19.74720	0.0097	0.010	0.116	0.2023
Neck weight and composition					
Total weight (kg)	−0.12840	0.0329	0.410	0.638	<.0001
Weight of lean meat (kg)	0.42850	0.0231	0.320	0.569	<.0001
Lean meat proportion (%)	97.64950	−0.1119	0.070	−0.260	0.0037
Subcutaneous fat weight (kg)	−0.55690	0.0097	0.200	0.446	<.0001
Subcutaneous fat proportion (%)	2.35050	0.1119	0.070	0.260	0.0037
IMF (%)	12.25440	−0.0480	0.010	−0.114	0.2340
Protein (%)	19.68540	0.0078	0.000	0.064	0.4870
Joint weight and composition					
Total weight (kg)	−1.20690	0.0849	0.580	0.764	<.0001
Weight of lean meat (kg)	1.97950	0.0357	0.210	0.463	<.0001
Lean meat proportion (%)	101.49980	−0.2620	0.140	−0.372	<.0001
Subcutaneous fat weight (kg)	−3.18630	0.0492	0.340	0.583	<.0001
Subcutaneous fat proportion (%)	−1.49980	0.2620	0.140	0.372	<.0001
IMF (%)	−0.82000	0.0202	0.100	0.323	0.0004
Protein (%)	25.13560	−0.0128	0.010	−0.073	0.4264

with increasing live weight (above 100 kg), the lean meat proportion decreases and the ratio of subcutaneous fat increases. For the ham and shoulder this trend was confirmed at a live weight of above 105 kg. The results determined correspond with those of Landgraf et al. (2002), who concluded that maximum fat deposition took place between 60 and 90 kg of live weight.

The maximum decline of the lean meat proportion (with increasing fat) at growing weight was determined in the joint (difference 4.19%), ham (3.9%), shoulder (3.0%) and neck (2.31%).

Concerning the influence of increasing weight on IMF, it is obvious that moderate growth occurs. In this respect, differences between group 1 and 5 were: 2.2% (ham), 1.65% (neck), 0.96% (shoulder) and 0.75% (joint). The values determined were not statistically significant with the exception of the joint. The highest increase was detected in the ham. The results identified correspond with

Table 6. Influence of sex on IMF content and carcass value of selected cuts in pigs

Sex	1		2		Alfa
	LSMEAN	SE	LSMEAN	SE	
Ham weight and composition					
Total weight (kg)	13.03	0.12	13.21	0.15	0.3481
Weight of lean meat (kg)	10.18	0.12	10.58	0.15	0.0405
Lean meat proportion (%)	78.25	0.46	80.14	0.60	0.0131
Subcutaneous fat weight (kg)	2.85	0.06	2.63	0.08	0.0287
Subcutaneous fat proportion (%)	21.75	0.46	19.86	0.60	0.0131
IMF (%)	3.23	0.28	3.71	0.25	0.1650
Protein (%)	22.18	0.13	22.18	0.17	0.9871
Shoulder weight and composition					
Total weight (kg)	6.27	0.05	6.28	0.07	0.8821
Weight of lean meat (kg)	4.56	0.05	4.67	0.07	0.2088
Lean meat proportion (%)	72.80	0.58	74.42	0.75	0.0866
Subcutaneous fat weight (kg)	1.71	0.04	1.61	0.05	0.1131
Subcutaneous fat proportion (%)	27.20	0.58	25.58	0.75	0.0866
IMF (%)	2.56	0.12	2.36	0.14	0,2933
Protein (%)	20.78	0.11	20.90	0.15	0.5038
Neck weight and composition					
Total weight (kg)	3.87	0.05	3.79	0.07	0.3825
Weight of lean meat (kg)	3.21	0.04	3.23	0.05	0.7354
Lean meat proportion (%)	83.28	0.43	85.59	0.56	0.0012
Subcutaneous fat weight (kg)	0.66	0.02	0.56	0.03	0.0071
Subcutaneous fat proportion (%)	16.72	0.43	14.41	0.56	0.0012
IMF (%)	6.69	0.33	5.97	0.39	0.1669
Protein (%)	20.59	0.14	20.80	0.18	0.3612
Joint weight and composition					
Total weight (kg)	8.90	0.10	8.95	0.13	0.7795
Weight of lean meat (kg)	6.11	0.08	6.40	0.11	0.0327
Lean meat proportion (%)	69.16	0.62	72.10	0.81	0.0041
Subcutaneous fat weight (kg)	2.79	0.07	2.54	0.09	0.0330
Subcutaneous fat proportion (%)	30.84	0.62	27.90	0.81	0.0041
IMF (%)	1.61	0.082	1.56	0.09	0.6920
Protein (%)	23.44	0.25	23.97	0.32	0.1988

1 = barrows; 2 = gilts

those of Okrouhlá et al. (2006). Matoušek et al. (1997) reported an average IMF content of 2.39% in hybrid populations. The conclusions of Fischer (2001) and Okrouhlá et al. (2006) were confirmed – maximum IMF values were detected in the neck (5.57% and 7.22%, respectively), ham (2.43% and 4.67%, respectively), shoulder in the *m. triceps brachii* (1.75% and 2.71%, respectively); the joint showed the lowest values (1.13% and 1.88%, respectively).

Concerning protein, no relation to increasing weight was found; the highest values were obtained in the joint muscle (23.56% and 23.87%, respectively). Okrouhlá et al. (2006) reported similar results. Pipek and Pour (1998) found the pork protein content to be in the range of 18–22%.

Table 5 characterizes the estimation of regression and correlation coefficients of selected traits and live weight. A significant positive correlation between live weight and lean meat, subcutaneous fat weight and fat proportion was found; a negative correlation with lean meat proportion was found as well. After the evaluation of live weight parameters, the fastest growth of subcutaneous fat and decreasing lean meat proportion were observed in the joint, shoulder, ham and neck.

Concerning the relationship between increasing weight and IMF content, statistically significant dependences and correlations were found only in the joint. The protein in the specific carcass cuts was not affected by increasing weight.

The influence of sex on IMF content and on the carcass value for selected carcass parts is shown in Table 6. It was found that at the same weights gilts attained a statistically significant lean meat proportion, excluding the shoulder, where the ascertained difference was not statistically significant – consistent with Tischendorf et al. (2002), Cassady et al. (2004), Bahelka et al. (2007). The maximum difference was found in the joint 2.9%, neck 2.3%, ham 1.8%; the lowest in the shoulder 1.6%. Opposite trends were observed for the subcutaneous fat proportion. The results show the higher ability of gilts to deposit muscle in all the monitored parts compared to barrows; the maximum differences were found for the most valuable carcass parts.

Concerning the IMF content, it was demonstrated that barrows attained a statistically higher ratio compared with gilts, excluding the ham, corresponding to the findings of Hamilton et al. (2000), Faucitano et al. (2004) and Latorre et al. (2004). On the contrary, Latorre et al. (2003), Correa et al. (2006) and Bahelka et al. (2007) presented statistically significant differences in IMF between the two sexes .

No influence of sex on the protein proportion in the monitored carcass parts was found.

CONCLUSION

Based on the ascertained values increased lean meat and subcutaneous fat weights were found to correlate with increasing weight in all monitored carcass cuts. With increasing live weight (above 100 kg), the lean meat proportion decreased and that of subcutaneous fat increased. For the ham, this trend was confirmed from the live weight of about 105 kg. The maximum decrease in lean meat proportion and the increase in fat proportion (with increasing weight) were found for the joint. A moderate growth of IMF with increasing body weight was detected, along with significant differences in IMF content among the specific parts. Concerning protein, no relationship to increasing weight or sex was found; maximum values were shown in the muscle of the joint. Gilts attained a significantly higher lean meat proportion. In barrows a statistically questionable IMF content was found as compared with gilts, with the exception of the ham.

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