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Effect of growth rate on carcass fat and fatty acid composition of rabbit meat and fat*

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The aim of the study was to determine the fat content of carcasses from rabbits differing in their rate of growth and to compare the composition of fatty acids in the intramuscular fat of the saddle and hind leg, subcutaneous fat, and organ fat. The experiment used New Zealand White rabbits divided into three groups depending on their rate of growth from weaning on day 35 to 90 days of age. The amount of subcutaneous, organ and intramuscular fat was analysed in the muscle lipids of the saddle and hind leg. The fat was analysed for the content of fatty acids. The study showed that the growth rate of rabbits has a highly significant effect on carcass fat. An increase in body weight was accompanied by an increase in subcutaneous and organ fat, but the growth rate had no effect on the intramuscular fat content of lipids in the meat of the hind leg and saddle. The fatty acid profile of rabbit fat varies according to the location on the carcass. The nutritionally most favourable ratio of *n-6* to *n-3* fatty acids was found in organ and subcutaneous fat, due to the highly significantly lower level of *n-6* polyunsaturated fatty acids – linoleic and arachidonic. The DFA/OFA and UFA/SFA ratios were less favourable.

KEY WORDS: rabbit / growth rate / fatty acid profile / fat content / SFA / MUFA / PUFA

The contemporary consumer is interested in proper nutrition and avoids excessive amounts of fats, especially those with an unfavourable composition. Numerous scientific studies have shown the adverse effects of a diet rich in saturated fatty acids and unsaturated fatty acids with *trans* configurations (TFA) on human health. Epidemiological studies show that their consumption in excess amounts is positively correlated with the risk of ischaemic heart disease, cancer, diabetes and obesity [1, 19].

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Of the four types of unsaturated fatty acids, it is mainly two families that exhibit specific biological activity, *n-3* and *n-6*, which play important but different roles in the human body. Long-chain polyunsaturated fatty acids of the *n-3* family – docosahexaenoic acid (DHA, 22:6 *n-3*) and eicosapentaenoic acid (EPA, 20:5 *n-3*) – are particularly important for proper functioning of the nervous and circulatory systems [1]. According to nutritional recommendations, the ratio of *n-6* to *n-3* fatty acids in the diet is important and should be 4-5:1, and no higher than 10:1. An excessive disproportion between these families may cause an imbalance in the amount of synthesized, often antagonistic eicosanoids, leading to certain pathological conditions [7, 18]. Therefore, diet modification can be an important element in the prevention and treatment of many diseases.

In Poland, the last few years have seen a steady increase in the consumption of rabbit meat, which is considered to be easily digestible, low in fat and low in cholesterol. It contains a high proportion of linolenic acid (C18:3 *n-3*) and is rich in essential amino acids and minerals.

Subcutaneous and organ fat in rabbits of meat breeds fed complete compound feeds, with a slaughter weight from 3.0 to 3.5 kg, may amount to 70 to 140 g, which is 2.3-4.0% of the carcass weight, while intramuscular fat may account for 0.3-14.6%, depending on the part of the carcass [13]. The fat content is influenced by factors including age at slaughter, growth rate and diet.

At rabbit breeding facilities, as in breeding of other animals, increasing attention is paid to reducing fat content and improving lean meat content, while maintaining the processing suitability and flavour of the meat. Optimum intramuscular fat content is known to give meat the desired flavour, juiciness and tenderness, which is one of the most important parameters determining the consumer's assessment of meat quality. Reducing intramuscular fat content to less than 1% has a negative effect on the flavour of meat, which becomes dry and tough, particularly after cooking.

The aim of the study was to determine the fat content of carcasses of rabbits with varied growth rates, slaughtered at 90 days of age, and to compare the fatty acid composition in the intramuscular (saddle and hind leg), subcutaneous and organ fat.

Material and methods

The study was conducted in 2012-2013 on a rabbit farm belonging to the National Research Institute of Animal Production in Aleksandrowice (the study was approved by the Local Ethics Committee at the Institute of Pharmacology, Polish Academy of Sciences, Krakow, No. 818). The experiment was conducted on a total of 120 New Zealand White rabbits. The rabbits, which were weaned at 35 days of age, came from different litters numbering 3 to 8 kits. The weight of the weaned rabbits was varied and ranged from 610 to 860 g.

During the experiment the rabbits were fed ad libitum a standard complete feed containing 16.0% crude protein, 3.5% crude fat, and 11.5% crude fibre. The feed consisted of

dried alfalfa, wheat bran, barley meal, maize meal, soybean extraction meal, milk replacer, feed phosphate, NaCl and a mineral and vitamin supplement together with a coccidiostat (robenidine).

At the end of the experimental rearing period (age 90 days), three groups were formed, each consisting of 10 rabbits (5 male and 5 female) with a body weight of 2.0 to 2.5 kg (group I), 2.5 to 3.0 kg (group II) and over 3 kg (group III). After 24-hour fasting, the animals were slaughtered in a slaughterhouse at the Institute in accordance with the procedures for this group of animals (Council Regulation (EC) No 1099/2009).

Immediately after slaughter a slaughter analysis was performed. The following data were collected: rabbit body weight after 24-hour fasting, weight of edible parts (carcass, liver, heart, kidneys and lungs), waste (skin tissue with hair, blood, legs and gastrointestinal tract) and slaughter losses. The dressing percentage was calculated as the ratio of the hot carcass weight with the head and edible organs to the weight of the animal before slaughter, according to the following formula:

$$WR(\%) = \frac{MT \times 100}{MC}$$

where:

WR – dressing percentage (%)

MT – carcass weight (g) with edible organs (liver, kidneys, lungs and heart)

MC – body weight before slaughter (g)

After 24-hour cooling (4°C), the carcasses were divided into primal cuts, to obtain the head – after cutting at the atlanto-occipital joint; the anterior part – after cutting between the last thoracic and first lumbar vertebrae; the saddle – after cutting behind the last lumbar vertebra; and the rear part – the remainder after cutting off the saddle, including the sacral region with the hind legs. Subcutaneous fat was separated with a scalpel – in the anterior part from the scapular region and in the posterior part from the inguinal region area. Organ fat in the middle part was taken from the kidney and stomach region. Individual fats were weighed.

Meat and fat samples were tested at the Central Laboratory of the National Research Institute of Animal Production in Aleksandrowice. Intramuscular fat was determined in 50 g meat samples from the thigh (biceps femoris muscle) and the saddle (longissimus lumborum muscle), which are the parts most favoured by consumers. Meat without the membranes and tendons was ground once in a grinder, using a plate with holes 3 mm in diameter. Intramuscular fat content was determined by the Soxhlet method according to PN-ISO 1444:2000.

The content of fatty acids was determined in freeze-dried samples of meat and fat, extracted with a chloroform and methanol solution according to Folch et al. [5]. Methyl esters of fatty acids were prepared according to ISO 12966-2:2011. The fatty acid profiles

of the methyl esters were determined by gas chromatography using a VARIAN 3400 gas chromatograph with a flame ionization detector, with an injector temperature of 250°C and a Rtx 2330 column (105 m x 0.32 mm x 0.2 μ). Helium was used as the carrier gas at a flow rate of 3 ml/min and the size of injected samples was 0.7 mcl. Acid standards from Larodan Fine Chemicals AB were used to determine CLA, and Sigma-Aldrich standards for other acids.

Saturated fatty acids (SFA) and unsaturated fatty acids (UFA), including monounsaturated (MUFA) and polyunsaturated (PUFA), were included in the analysis. In addition, the content of hypocholesterolaemic (DFA) and hypercholesterolaemic fatty acids (OFA) and the DFA/OFA and UFA/SFA ratios were calculated.

Statistical analysis of the results was performed using one-way analysis of variance (ANOVA). The significance of differences between means in groups was estimated by Duncan's multiple range test. Coefficients were estimated in Statistica 8 software (StatSoft, USA, 2008).

Results and discussion

Adipose tissue is the last type of tissue to develop, after nervous, bone and muscle tissue. From birth to physical maturity, muscles increase their absolute mass faster than fat. Animals stop growing when they reach somatic maturity [4]. In rabbits, this takes place in the second year of life, but depending on the breed, weight gain continues until the 7th to 10th month. Increasing body weight is accompanied by changes in the proportion of carcass tissues. As fat content increases, the share of muscles and the weight of valuable cuts decreases.

Slaughter of rabbits of the same age (90 days) but with different body weights showed that the animals weighing more at slaughter had more fat, and thus reached slaughter maturity earlier. Significant differences ($P \leq 0.01$) were observed in total fat (organ and subcutaneous) in all groups (Table 1). No differences were noted between groups in the weight of the liver, heart, kidneys, lungs or blood. Differences ($P \leq 0.01$) were found in the weight of the edible parts and the skin tissue with the hair between all groups, in the weight of the legs between groups I and III, in the weight of the gastrointestinal tract between groups I and II and group III, and in the total weight of inedible parts between groups I and III. Significant differences ($P \leq 0.05$) were found for dressing percentage between group I and groups II and III. Corino et al. [2], in a study conducted on New Zealand White rabbits slaughtered at 2.5 kg body weight, obtained a 59.5% dressing percentage, as compared to 60.3% for slaughter at 2.8 kg and 61.4% at 3.2 kg. In our study, the ratio of edible to inedible parts increased with slaughter weight.

When the weights of individual edible and inedible parts were expressed as a percentage of body weight, the share of edible parts, including fat, was found to increase with the body weight, while the share of organs and waste decreased (Table 2).

Similar results were obtained by Murawska et al [12] for broiler chickens: the proportion of edible and inedible parts changed as the body weight of the birds increased.

Table 1
Slaughter analysis

Specification	Group		
	I	II	III
Body weight of rabbit (g)	2269.2^{A}	2749.8^{B}	3100.0^{C}
Weight of carcass with head (g)	1197.4^{A}	1528.3^{B}	1745.0^{C}
Liver (g)	85.0	86.6	95.0
Heart, kidneys, lungs (g)	38.3	43.3	40.0
Total fats (g)	40.2^{A}	63.5^{B}	93.83^{C}
Total edible parts (g)	1360.9^{A}	1721.7^{B}	1973.8^{C}
Skin tissue with hair (g)	357.5^{A}	413.2^{B}	450.0^{C}
Blood (g)	75.8	78.3	76.2
Legs (g)	65.0^{A}	98.3^{B}	94.9^{B}
Digestive tract (g)	410.0^{A}	438.3^{A}	505.1^{B}
Total inedible parts (g)	908.3^{A}	1028.1^{AB}	1126.2^{B}
Dressing percentage	58.2^{a}	60.3^{b}	60.6^{b}
Ratio of edible to inedible parts	1.5:1	1.7:1	1.7:1

Values denoted by different letters in rows differ statistically significantly: A, B – P≤0.01; a, b – P≤0.05

This was due to the substantial, 42-fold increase in the weight of edible parts in the first 10 weeks of life of the chickens, while the weight of inedible parts increased about 20-fold.

Adipose tissue is no longer seen exclusively as an energy storehouse, but is believed to be actively involved in metabolic changes in the body. The composition of the carcass and especially its fat content depend on a number of factors, including gender, age, feeding level and genetic potential, which is largely associated with the type of animal (characterized by early, intermediate or late maturation) [17]. In our study, no differences were observed in the fat content of carcasses of male and female rabbits aged 90 days. In all groups, the level of organ fat significantly (P≤0.01) increased with weight gain. The amount of subcutaneous fat varied significantly (P≤0.01) between group I and groups II and III. There were no statistically significant differences in intramuscular fat content in the muscle tissues of the hind leg and saddle (Table 3).

Table 2
Weight of edible and inedible parts as a percentage of body weight (%)

Specification	Group		
	I	II	III
Weight of carcass with head	52.7	55.6	56.3
Liver	3.74	3.14	3.06
Heart, kidneys, lungs	1.68	1.57	1.29
Total fats	1.77	2.31	3.03
Total edible parts	59.9	62.6	63.67
Skin tissue with hair	15.7	15.0	14.5
Blood	3.34	2.85	2.46
Legs	2.86	3.57	3.06
Digestive tract	18.06	15.9	16.3
Total inedible parts	40.02	37.4	36.3

Table 3
Percentage of organ, subcutaneous and intramuscular fat depending on body weight

Group	Mean body weight	Organ fat	Subcutaneous fat	Intramuscular fat – hind leg	Intramuscular fat – saddle
I	2269.2^{A}	37.0^{A}	3.17^{A}	3.02	1.78
II	2749.8^{B}	52.5^{B}	8.00^{B}	3.60	2.28
III	3100.0^{C}	82.8^{C}	11.0^{B}	4.28	2.25

Values denoted by different letters in a column differ statistically significantly: A, B – $P \leq 0.01$

Maj et al. [10] reported the fat content of the saddle of New Zealand White rabbits as 1.60%, while Szkucik and Libelt [15] reported 1.12%, and Kowalska and Bielański [8] 2.11%. Much lower values were obtained by Daszkiewicz et al. [3]; the average proportion of fat in the thigh meat was 0.69%, which was 0.36 pp higher than in the longissimus lumborum muscle. Ramirez et al. [14], in a study conducted on two groups of rabbits with

different growth rates, slaughtered at 9 weeks of age, observed an increase in intramuscular fat in the hind leg (from 2.97% to 3.21 %) as body weight increased.

Fatty acids, whose properties depend on the length of the hydrocarbon chain and the number of unsaturated bonds, have a decisive effect on fat quality. In our study, no statistically confirmed differences were found in the percentage composition of fatty acids between weight groups, so the results are presented for all groups combined.

Organ fat and subcutaneous fat had higher content of medium-chain fatty acids (MCFA): caprylic (C8:0), decanoic (C10:0), and lauric (C12:0). Palmitic acid (C16:0), predominant among saturated fatty acids, was present in the smallest amount in the intramuscular fat of the saddle and hind leg muscles ($P \leq 0.01$), which led to a lower proportion of SFAs. A significant ($P \leq 0.01$) reduction in stearic acid (C18:0) was also noted in the organ fat and subcutaneous fat relative to the intramuscular fat of the hind leg. Szkucik and Ziomek [16] found no differences in the amount of saturated acids (except stearic acid) depending on the location of adipose tissue.

One of the most important fatty acids with beneficial health-promoting effects is oleic acid (C18:1 from the *n-9* family), which blocks the absorption of cholesterol from food, lowers LDL content, and reduces blood viscosity and pressure. Others include linoleic acid (C18:2 from the *n-6* family) and arachidonic acid synthesized from it (C20:4, prostaglandin and leukotriene precursor) and *n-3* fatty acids – eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These acids are essential for normal growth and development of the body, prevent coronary heart failure, increase immunity, participate in lipid transport, including cholesterol, and lower peripheral blood cholesterol [1, 7]. An imbalance of the *n-6/n-3* ratio is considered a risk factor for human health. Analysis of the content of *n-6* fatty acids in the test samples (Table 4) revealed a significant increase in linoleic acid in the intramuscular fat of the saddle and hind leg. The highest content of arachidonic acid was found in the hind leg muscles and the lowest in the organ fat and subcutaneous fat. Szkucik and Ziomek [16] reported different results for linoleic acid [16], as they found the highest level of this acid in the organ fat (18.28%), slightly less in the subcutaneous fat (17.38%) and the least in the intramuscular fat (16.71%).

Content of acids of the *n-3* family showed a slight upward trend (not confirmed statistically) for linolenic acid in the subcutaneous fat. EPA and DHA levels were highest in the intramuscular fat of the hind leg and lowest in the organ fat and subcutaneous fat ($P \leq 0.01$). In the study cited above [16], the intramuscular fat also had the highest content of EPA and DHA.

Organ fat and subcutaneous fat had the highest ($P \leq 0.01$) content of saturated fatty acids (SFA) and lowest of unsaturated fatty acids (UFA). The greatest differences in the content of unsaturated fatty acids were found for the *n-6* family, with higher content in the meat of the saddle and hind leg ($P \leq 0.01$). The content of *n-3* acids was similar in all samples. Particularly noteworthy is the significantly lower *n-6*/*n-3* ratio in the organ fat (4.84) and subcutaneous fat (4.72) as compared to the intramuscular fat of the saddle

Table 4
Content of some fatty acids in lipids (% of total acids)

Fatty acid	Intramuscular fat – saddle	Intramuscular fat – hind leg	Organ fat	Subcutaneous fat
C8:0	0.000^{A}	0.000^{A}	0.006^{A}	0.022^{B}
C10:0	0.224^{ab}	0.180^{a}	0.248^{ab}	0.476^{b}
C12:0	0.284^{ab}	0.269^{a}	0.363^{ab}	0.468^{b}
C14:0	3.395^{A}	3.413^{A}	4.956^{B}	4.834^{B}
C16:0	29.33^{A}	30.04^{A}	34.68^{B}	33.87^{B}
C16:1	3.671	4.574	4.892	4.821
C18:0	5.646	5.931^{A}	5.247^{B}	5.241^{B}
C18:1	27.584^{a}	25.861^{b}	25.947^{b}	25.972^{b}
C18:2 *n-6*	22.868^{A}	21.365^{A}	18.816^{B}	19.152^{B}
Gama 18:3	0.0508	0.0648	0.0456	0.0571
C20:0	0.1098^{Aa}	0.0885^{Ab}	0.0332^{B}	0.0400^{B}
C18:3 *n-3*	3.9890	3.7986	3.9301	4.0945
C22:0	0.0943	0.0161	0.000	0.000
C20:4 *n-6*	1.808^{A}	3.445^{B}	0.3265^{C}	0.3540^{C}
C22:1	0.0390^{A}	0.0275^{A}	0.000^{B}	0.000^{B}
CLA *c*9-*t*11	0.5675	0.5140	0.4435	0.4941
CLA *t*10-*c*12	0.008	0.000	0.0345	0.0161
CLA *c*9-*c*11	0.0136^{A}	0.0073^{A}	0.0000^{B}	0.0000^{B}
CLA *t*9-*t*11	0.0321	0.0103	0.0195	0.0240
C20:5 *n-3* (EPA)	0.1120^{A}	0.2055^{B}	0.0270^{C}	0.0326^{C}
C22:6 *n-3* (DHA)	0.0340^{A}	0.1860^{B}	0.0095^{A}	0.0280^{A}
SFA	39.086^{A}	39.940^{A}	45.534^{B}	44.952^{B}
UFA	60.914^{A}	60.059^{A}	54.465^{B}	55.047^{B}
MUFA	31.295	30.462	30.840	30.793
PUFA	29.619^{A}	29.596^{A}	23.625^{B}	24.253^{B}
PUFA *n-6*	24.726^{A}	24.875^{A}	19.188^{B}	19.564^{B}
PUFA *n-3*	4.135	4.190	3.966	4.155
DFA	66.560^{A}	65.991^{A}	59.712^{B}	60.288^{B}
OFA	33.439^{A}	34.008^{A}	40.287^{B}	39.711^{B}
DFA/OFA	1.992^{A}	1.945^{A}	1.487^{B}	1.523^{B}
UFA/SFA	1.559^{A}	1.506^{A}	1.199^{B}	1.227^{B}
MUFA/SFA	0.800^{A}	0.762^{A}	0.678^{B}	0.686^{B}
PUFA/SFA	0.759^{A}	0.743^{A}	0.520^{B}	0.541^{B}
PUFA *n-6/n-3*	5.979^{a}	5.949^{a}	4.837^{b}	4.715^{b}
CLA	0.614	0.531	0.470	0.534

Values denoted by different letters in rows differ statistically significantly: A, B – P≤0.01; a, b – P≤0.05

(5.98) and hind leg (5.95). The reverse pattern was reported by Szkucik and Ziomek [16]: 9.41 and 9.38 in the organ fat and subcutaneous fat, respectively, and 6.29 in the intramuscular fat of the thigh and shoulder. Despite the highly significantly lower con-

tent of hypocholesterolaemic (cholesterol-reducing) acids (DFA) in the organ fat and subcutaneous fat, the DFA/OFA ratio was more favourable in the intramuscular fat of the saddle and leg ($P \leq 0.01$), as was the UFA/SFA ratio. Ramirez et al. [14] showed changes in the fatty acid profile of rabbit meat, i.e. an increase in myristic, palmitic, palmitoleic and oleic acid in the group selected for growth rate. These changes, however, did not affect the health-promoting value of the rabbit meat.

In recent years, increasing attention has been paid to conjugated linoleic acid (CLA). This is a group of linoleic acid derivatives occurring in the form of positional and geometric isomers. The highest amounts of CLA are found in ruminant food products. The presence of CLA in ruminant tissues is associated with the activity of bacteria such as *Butyrivibrio fibrisolvens*, involved in the biohydrogenation of unsaturated fatty acids in the fat of the feed ration; CLA is an intermediate product resulting from incomplete hydrogenation of linoleic acid [20]. CLA, like other PUFAs, can inhibit the formation and development of cancers, exhibits antimutagenic activity, lowers cholesterol, especially LDL, prevents diet-induced atherosclerosis, improves bone structure, and stimulates fat and protein synthesis [6, 9, 18].

CLA was present in all samples tested, but the CLA *c*9-*c*11 isomer was not present in the organ fat or subcutaneous fat, and CLA *t*10-*c*12 was not found in the lipids of the hind leg. Mauronek et al. [11] reported similar CLA values in saddle muscle lipids – 0.9 mg/g of fatty acids, and 0.5 mg/g of fatty acids in the hind leg and kidney fat.

The research showed that the growth rate of rabbits has a highly significant influence on carcass fat. As body weight increases, the amount of subcutaneous and organ fat increases as well, but growth rate does not affect the intramuscular fat content in the lipids of the hind leg and saddle. The fatty acid profile of rabbit fat varies depending on the location in the carcass. The organ fat and subcutaneous fat had the most beneficial *n-6*/*n-3* ratio in terms of human health, due to a significantly lower ($P \leq 0.01$) level of *n-6* polyunsaturated acids, i.e. linoleic and arachidonic acid. The DFA/OFA and UFA/SFA ratios were less favourable.

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