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Influence of Genotype Lines, Age at Slaughter and Sexes on the Composition of Rabbit Meat

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Summary

Chemical composition (water, proteins, ash, intramuscular fat, cholesterol, fatty acid composition), sensory characteristics and instrumental profiles (colour and texture) of lean rabbit meat were investigated. It originated from animals of three different lines of SIKA genotype (A – mother line, C – father line, AC – hybrid of mother and father lines), two animal ages at slaughter (93 and 105 days) and both sexes. Rabbits were fed a commercial diet *ad libitum*. The boneless muscles of the back (*longissimus lumborum*) including muscles of abdominal wall and hind legs were sampled from thirty-six animals. On the average rabbit meat contains 71.5 % of water, 22.0 % of proteins, 1.17 % of ash, 5.4 % of intramuscular fat, 67.6 mg of cholesterol per 100 g of fresh meat, and as for fatty acid composition, 34.1 % belong to monounsaturated, 25.1 % to polyunsaturated and 40.9 % to saturated fatty acids. The P/S mass ratio (0.62), the atherogenic index (0.70), the *n*-6/*n*-3 ratio (8.1) and the cholesterol content show that the rabbit meat can and should be included into a balanced human diet. Meat of female rabbits contains more intramuscular fat and cholesterol compared to the male ones (5.7 *vs.* 5.2 g of intramuscular fat/100 g; $p \leq 0.05$; 71.5 *vs.* 63.7 mg of cholesterol/100 g, respectively; $p \leq 0.01$). Genotype line does not affect either the fatty acid profile or the content of cholesterol, but it has a significant impact on intramuscular fat (A line 5.0 g/100 g; AC line 5.9 g/100 g; C line 5.4 g/100 g; $p \leq 0.05$) as well as on cutting values across the fibres (Instron apparatus; A line 43 N; AC line 38 N; C line 42 N; $p \leq 0.05$). Meat of 105-day-old rabbits contains more intramuscular fat (5.7 *vs.* 5.2 g/100 g; respectively; $p \leq 0.05$) and shows darker and redder colour (both sensorially evaluated colour as well as instrumentally measured L^* and a^* values; $p \leq 0.01$) compared to the 93-day-old ones.

Key words: rabbit meat, chemical composition, fatty acid composition, cholesterol, sensory properties

Introduction

In a diet, meat is considered a major source of fat, especially of saturated fatty acids, which are as a rule considered a risk for diseases associated with modern life, mostly in developed countries (*1*). From the nutritional viewpoint, rabbit meat is well appreciated for its favourable properties: it is lean, rich in unsaturated fatty acids (60 % of all fatty acids) and low in cholesterol in comparison with usually consumed red meat (*2*). The data on chemical composition of rabbit meat, especially those on fat content and fatty acid profile exhibit a relatively pronounced diversity and depend on genotype, feeding, age, breeding and/or physical activity of the animal as well as on the muscle type and the sex of the animals in question. References on fat content in rabbit

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meat are very frequent in literature and according to the statement by Dalle Zotte and some other authors (*2–5*) it varies between 0.6 and 14.4 %, depending on factors mentioned above. Fatty acid composition varies and is expressed as share of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), PUFA/SFA (P/S) and n-6/n-3 indexes (*2,4,6–8)*. Data on cholesterol content are between 45 and 85 mg/100 g of meat (*2,9,10*). Rabbit meat is also rich in proteins (20.0–21.9 %), its amino acids have a high biological value, its energy values are comparable (427–849 kJ/100 g of fresh meat) to various usually consumed varieties of red meat (*2,11*). In addition to nutritional parameters the sensory properties of meat are crucial for the consumer's choice. Consumers consider that rabbit meat has attractive sensory properties: it is tender, lean and delicately flavoured (wild taste). The main cause of a potential refusal is its typical taste of wild game meat as sometimes mentioned by the consumers (*2*).

We anticipated that line (A, AC, C) of SIKA genotype (Slovenian meat line), animal age at slaughter (93 *vs.* 105 days) and sex (male *vs.* female) can affect the chemical composition (cholesterol content and also fatty acid profile) as well as the sensory, colour and texture profiles of rabbit meat and consequently systematic comparisons were made.

Material and Methods

Animals

A total of thirty-six rabbits was included in the study. They were fed a diet containing the standard feed mixture Kand/stand (170 g CP/kg, 140 g CF/kg, 10.4 MJ DE/kg) *ad libitum*. Data on the measurements of rabbit carcasses are presented in Table 1. The study included three different lines (A – mother line, C – father line, AC – hybrid of mother and father lines) of SIKA genotype, two ages at slaughter (93 and 105 days) and both sexes. Therefore, the study consisted of 36 rabbits, 12 of A line, 12 of C line and 12 of AC line. Half of them (6) was 93 days old and half of them (6) 105 days old at slaughter; within each age-group there were 3 male and 3 female rabbits. After electro-stunning, the rabbits were slaughtered by cutting the carotid and jugular veins.

Tissue sampling

At the slaughterhouse the carcasses were eviscerated and stored for 24 h at the temperature of (4±1) °C. Total dissectible fat was eliminated manually. The *longissimus lumborum* (LL) muscle between the 1st and the 7th lumbar vertebra, including the muscles of abdominal wall (flank) and hind legs, were removed from carcasses as samples for further analyses. All samples were divided into two subsamples, the first (the right LL muscle) was used for L*a*b* colour and ultimate pH (pH_u) measurements. Then the right LL muscles were homogenized in a blender together with hind leg muscles and muscles of abdominal wall, packed into polyethylene bags, frozen and stored at the temperature of (-21±1) °C for determination of water, protein, ash, fat and cholesterol content, as well as for the analysis of fatty acid composition. All analyses were carried out in duplicate. On the second subsample (the left back (LL with bones) and the muscles of abdominal wall) thermal treatment was performed (roasting at 175 °C to the internal temperature of (77 ± 1) °C. Roasted samples were prepared for sensory analysis and for instrumental measuring of the texture.

Determination of colour and pH_u value

The L*a*b* colour was evaluated instrumentally on the freshly cut slice of raw LL muscles at 1st lumbar vertebra. Four measurements of CIE L*, a*, b* values were made on the slice of each sample. Preparation of the samples and the conditions for the assessment of the colour (*12*) were as follows: a Minolta CR 200b colorimeter (Illuminant C, 0° viewing angle) was used to determine the CIE L* (lightness), a* (+/–, red to green), and b* (+/–, yellow to blue) values of the meat samples. A white ceramic tile with the specification of Y = 93.8, x = 0.3134, and y = 0.3208 was used to standardise the colorimeter.

pH_u was measured 24 h *post mortem* directly in raw LL muscle (1st lumbar vertebra) in duplicate using a spear combined glass-gel electrode type 03 (Testo pH electrode) connected to a pH meter (Testo 230, Testo). The pH meter was calibrated using pH=5 and pH=7 buffers and recalibrated after every 20 readings. Accuracy of reading was ±0.01 pH unit.

Determination of cutting values

Instrumental analysis of the sample texture was performed by apparatus Instron, type 1111, at the highest allowed load of 1000 N, at room temperature (24 °C). Cutting values (N) were measured on roasted and chilled slices of LL muscles (across and longitudinal to meat fibres, 10 mm thick) as the resistance of sample to the cutting strength of obtuse blade-shape cell (blade-length 10 mm; angle between blade sides 60°, diameter of obtuse point of a knife 1 mm, Fig. 1). The operating conditions were: blade speed 50 mm/min, penetration into muscle 9.4 mm. Cutting values (N) on the samples were determined in four repetitions.

Table 1. Live mass and slaughter yield from rabbits of three SIKA genotype lines and two ages at slaughter (*N*=36)

Genotype line	A line		AC line		C line	
Age at slaughter/day	93	105	93	105	93	105
Live mass/g	2755±224	3067±226	3094±283	3366±261	3214±323	3492±204
Slaughter yield/%	54.1±1.2	55.1±1.5	55.5±1.5	56.2±1.4	55.6±2.0	56.3±2.0

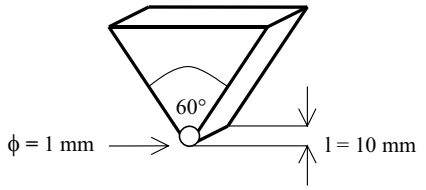

Fig. 1. Schematic presentation of Instron apparatus blade for measuring of cutting values

Water, protein and ash content

The water content was determined on the sample of 5 g of minced meat. Samples were dried in the oven at 105 °C according to AOAC 950.46 (*13*). Total protein (crude protein, N × 6.25) content was assessed by the Kjeldahl method according to AOAC 928.08 (*13*) (standard method). The ash content was determined by mineralisation of samples at 550 °C according to AOAC 920.153 (*13*) (standard method).

Intramuscular fat content

Intramuscular fat (IMF) content was determined by the method described in AOAC Official Method 991.36: Fat (Crude) in Meat and Meat Products (*13*).

Fatty acid composition

The fatty acid (FA) composition of samples was determined by gas-liquid chromatography (GLC). The method chosen was *in situ* transesterification (ISTE) of Park and Goins (*14,15*).

The content of fatty acid methyl esters (FAME) was determined by GLC on an Agilent Technologies 6890 gas chromatograph with a flame ionisation detector (FID) and the capillary column Supelco SP-2380 (60 m × 0.25 mm × 0.2 μm). Separation and detection were performed under the following conditions: temperature programme 170 °C, 8 min; 7 °C/min to 250 °C (19.43 min); temperature of the injector 250 °C; temperature of the detector 280 °C; injector: split:splitless 1:30, volume 1 mL; carrier gas: He 1 mL/min; make-up gas: N_2 45 mL/min; the gases in the detector: H_2 40 mL/min; synthetic air (21 % O_2) 450 mL/min.

FAME was determined through the retention times of the FAME in a standard mixture (Supelco fatty acid methyl ester mix of 37 components, Cat. No. 18919-1AMP). The same standard mixture was used to determine the response factor, $R_{f,i}$, for each fatty acid. The mass portion of each fatty acid in the sample was determined using the response factor and the factor of transformation of FA content from FAME content. Determination of reliability and accuracy of the analytical method for the quantitative determination of FA was ensured by the use of the certified reference matrix – CRM 163 (blend beef-pork fat – BCR) and is in good agreement with the certified values. The FAME were expressed in the percentage of total FA.

Cholesterol content

The cholesterol content in rabbit meat was determined according to the modified method by Naeemi *et al.* (*16*) followed by HPLC analyses and expressed in mg/100 g of fresh meat.

To an accurately weighed well-ground meat sample of (2±0.01) g spiked with internal standard (5 α-cholestane), 10 mL of saturated methanolic KOH were added in a 50-mL screw-capped vial. The vial was capped and then heated for 30 min at 80 °C. Into the cooled vial (20 °C), 10 mL of hexane were added, then the vial was closed and shaken vigorously for 2 min. Further on it was centrifuged at 1000 × *g* for 2 min. An aliquot of the hexane extract (5 mL) was dried *in vacuo* and freed of solvent by using a nitrogen flush before dissolving it in 2 mL of mobile phase and injecting into the HPLC system. For HPLC, Agilent technology system 1100 composed of Micro vacuum degasser G1379A, Binary pump G1312A, Autosampler thermostat G1367A, Thermostatted column compartment G1316A, Diode array and Multiple wavelenght detector G1315B was used. The analytical column was Hypersil ODS 5 μm, 150 mm × 4.6 mm. The mobile phase consisted of isopropanol/acetonitrile (45:55), the flow rate being 1.0 mL/min. Absorption was measured at 210 nm. Determination of reliability and accuracy of the analytical method for the quantitative determination of cholesterol was ensured by the use of the certified reference matrix – CRM 163 (blend beef-pork fat – BCR) and is in good agreement with the certified values.

Sensory analyses

For the purpose of evaluating sensory qualities, a panel composed of four qualified and experienced panellists in the field of rabbit meat was appointed, while sensory properties of coded samples were tasted in a standard sensory laboratory. The same panel evaluated all samples; the trial consisted of three sessions.

All testing posts in the sensory laboratory had identical conditions. The room temperature was approximately 20 °C and relative humidity was between 60 and 75 %. Lightning of the room was also the same throughout the experiment. Samples for the sensory analysis were prepared as follows: samples were roasted without salt or spices. The centres of roasted LL muscles were immediately cut into cube pieces of approximately 5 g. The panel assessed the warm samples separately one by one in three sessions composed of 12 samples (4 A line, 4 AC line and 4 C line). To neutralise the taste, the panel used the middle part of white bread and tepid lemon-flavoured water (concentration 1 %). The break between the sessions was one hour.

The analytical-descriptive (according to Golob *et al.* (*17*)) test was performed by scoring sensory properties using a non-structured scale from 1 to 7 points, where higher score means more expressed property. An exception was the colour, which was evaluated by scoring on a scale 1 – 4 – 7. The score of 4 points was considered optimal (colour of rabbit meat of normal quality), scores above 4 indicated dark red meat and those below 4 points indicated pale red meat. Sensory descriptors of roasted rabbit meat are the following:

- Smell: characteristic of rabbit meat smell
- Colour: intensity of red colour
- Tenderness: easiness of chewing

– Juiciness: water release at the beginning of chewing and salivation stimulated by the content of meat lipids
– Mouth feeling: smoothness of meat fibres during chewing
– Flavour: characteristic of rabbit meat flavour
– After-taste of rabbit flavour: intensity of rabbit meat flavour after swallowing.

Data analysis

The data for chemical parameters (four determinations of each treatment) were analysed by the method of the least squares using the GLM procedure (*18*). The data for sensory properties, which were not distributed normally were analysed using the NPAR1WAY procedure (nonparametric Wilcoxon test). The statistical model for the analysed parameters of rabbit meat included the effects of genotype (L), animal age at slaughter (A) and sex (S) (Eq. 1).

$$y_{ijkl} = \mu + L_i + A_j + S_k + e_{ijkl} \qquad /1/$$

where y_{ijkl} = the ijklth observation, μ = general mean value, L_i = effect of ith genotype line (i = 1 mother line – A, i = 2 hybrid of mother and father lines – AC, i = 3 father line – C), A_j = effect of jth age at slaughter (j = 1 93 days, j = 2105 days), S_k = effect of kth sex (k = 1 male, k = 2 female), and e_{ijkl} = residual random term with variance σ_e^2.

The means of the experimental groups were obtained using either Duncan or Wilcoxon test (*17*). Relations between sensory scores and chemical parameters were assessed by Pearson correlation coefficients using the CORR procedure.

Results and Discussion

Instrumental colour parameters and pH value

The instrumental parameters of rabbit meat colour differed significantly with the age at slaughter but not with genotype line or sex of the animals. The means of instrumental parameters of colour and statistical significance between different genotype lines, 93- and 105-day-old rabbits, and male and female animals are presented in Table 2. In our study, the colour changes observed between the samples of different lines and sexes are most probably coincidental and are not a result of myofibrilar protein shrinkage or of the accumulation of hem pigments. An exception was significantly darker and redder colour (the lowest L^*, the highest a^* values), which occurred in the older rabbits and probably resulted from their higher myoglobin content compared to the younger ones.

Several reports in literature deal with effects of genotype, diet, sex or slaughter age on $L^*a^*b^*$ colour parameters (*19–21*), but authors themselves mention that results are often contradictory, indicating on the one hand a possible lack of knowledge of these physicochemical traits of muscles and/or on the other hand errors of the methodology of such measurements.

There were no notable changes in pH_u values and the average of all our measurements was 6.03±0.07. Absolute pH_u values for SIKA genotype lines are relatively higher than we expected but are comparable to pH_{24} from different genotypes investigated by Barròn *et al.* (*22*). Researchers assure that depletion of glycogene reserves, as well as handling before slaughtering and processing factors, may cause high muscle pH values.

When meat quality was described by the physicochemical criteria (pH value, $L^*a^*b^*$ meat colour values) we determined that the differences between lines and sex groups tend to be small and rabbit meat quality seems to be rather constant. This statement is in agreement with findings in literature (*22,23*).

Cutting values

Table 2 also shows the effects of genotype lines, sex and animal age at slaughter on textural properties of roasted rabbit meat. Significantly higher cutting values across the fibres in A and C lines compared to AC line in the present study are not in accordance with sensory analysis of the same samples (Table 3), where the A and AC lines were found more tender. Nevertheless, the differences are not significant.

The age difference at slaughter (two weeks) was not big enough to result in notable changes in tenderness. Unexpectedly, there was not a significant difference between the samples of different sex.

Table 2. Instrumental colour and texture parameters of rabbit meat (muscles of the back), samples taken from animals of three genotype lines, two ages at slaughter and both sexes (*N*=36)

Effect of:	Genotype line				Sex			Age at slaughter/day		
Parameter	A line	AC line	C line	Sign.	Male	Female	Sign.	93	105	Sign.
L* value	58.9 ± 2.6	59.0 ± 2.2	58.1 ± 2.7	Ns	58.9 ± 2.5	58.4 ± 2.6	Ns	60.4 ± 1.7^a	57.0 ± 1.9^b	***
a* value	3.8 ± 1.4	3.4 ± 1.4	3.4 ± 1.2	Ns	3.8 ± 1.4	3.3 ± 1.2	Ns	2.9 ± 1.2^b	4.2 ± 1.2^a	**
b* value	4.5 ± 0.6	4.0 ± 1.1	3.9 ± 0.9	Ns	4.3 ± 1.1	4.0 ± 0.7	Ns	4.4 ± 0.8	3.9 ± 1.0	Ns
Cutting value longitudinal/N	36 ± 4	32 ± 5	34 ± 4	Ns	34 ± 4	34 ± 50	Ns	35 ± 5	33 ± 4	Ns
Cutting value across/N	43 ± 4^a	38 ± 4^b	42 ± 4^a	*	42 ± 4	40 ± 5	Ns	42 ± 5	40 ± 4	Ns

Mean values ± standard deviation in each group. *N* – number of observations. Means with a different superscript within groups differ significantly ($p \leq 0.05$). Sign. – statistically not significant: Ns – $p > 0.05$; statistically significant: * $p \leq 0.05$ and ** $p \leq 0.01$; highly statistically significant: *** $p \leq 0.00$

Table 3. Sensory properties of roasted rabbit meat (back muscles) from animals of three genotype lines, two ages at slaughter and both sexes (*N*=36)

Effect of:	Genotype line				Sex			Age at slaughter/day		
Properties (points)	A line	AC line	C line	Sign.	Male	Female	Sign.	93	105	Sign.
Smell (1–7)	5.4 ± 0.2	5.5 ± 0.2	5.4 ± 0.1	Ns	5.4 ± 0.2	5.4 ± 0.2	Ns	5.4 ± 0.2	5.4 ± 0.2	Ns
Colour (1–4–7)	3.1 ± 0.4	2.8 ± 0.5	3.1 ± 0.4	Ns	3.0 ± 0.5	3.0 ± 0.5	Ns	2.8 ± 0.4[b]	3.2 ± 0.4[a]	**
Tenderness (1–7)	5.5 ± 0.3	5.5 ± 0.3	5.3 ± 0.4	Ns	5.4 ± 0.3	5.4 ± 0.4	Ns	5.5 ± 0.4	5.4 ± 0.3	Ns
Juiciness (1–7)	4.2 ± 0.3	4.4 ± 0.3	4.3 ± 0.3	Ns	4.3 ± 0.3	4.3 ± 0.3	Ns	4.2 ± 0.2	4.3 ± 0.4	Ns
Mouth feeling (1–7)	4.7 ± 0.4	4.8 ± 0.3	4.6 ± 0.5	Ns	4.8 ± 0.4	4.6 ± 0.5	Ns	4.6 ± 0.4	4.8 ± 0.4	Ns
Flavour (1–7)	5.4 ± 0.1	5.4 ± 0.2	5.4 ± 0.3	Ns	5.4 ± 0.2	5.4 ± 0.2	Ns	5.4 ± 0.2	5.4 ± 0.2	Ns
Aftertaste of rabbit meat (1–7)	2.2 ± 0.3	2.0 ± 0.2	2.1 ± 0.2	Ns	2.1 ± 0.2	2.1 ± 0.2	Ns	2.1 ± 0.2	2.1 ± 0.2	Ns

Mean values ± standard deviation. *N* – number of observations. Means with a different superscript within groups differ significantly (p≤0.05). Sign. – statistically not significant: Ns – p>0.05; statistically significant: ** p≤0.01

Longitudinal cutting strengths and those across fibres were negatively related to sensorially evaluated tenderness in all three lines (Table 4).

Table 4. Correlations between instrumental texture parameters and tenderness of roasted rabbit meat

Genotype line	Tenderness		
	A	AC	C
Cutting value longitudinal	–0.70*	–0.34	–0.73**
Cutting value across	–0.52	–0.32	–0.30

Statistically significant: * p≤0.05 and ** p≤0.01

Water, protein and ash content

Table 5 shows the composition (water, ash and protein contents) of fresh LL muscles together with hind leg and of abdominal wall muscles for three genotype lines, both sexes and two ages at slaughter. The rabbit meat included in this investigation contains on average 71.5 % of water, 22.0 % of proteins and 1.17 % of ash.

Water content seems to be lower in older than in younger group (p≤0.01). These results agree with the conclusions of Gondret *et al.* (*24*); namely, that chemical composition of LL muscle is markedly affected by age, and water content declines with increasing age. Samples from different sexes show significantly higher water content in male rabbits (p≤0.05). Generally, our results about water content agree with those of other researchers, who found similar content of water in hind leg (*19, 23,25*) and in back muscles (*19,23,24*). Ash content exhibits marked differences due to age (p≤0.001) and sex (p≤0.05); the content of ash was higher in male than in female samples, and it decreased with age. Results about the effect of animal age at slaughter and sex on the ash content are partly contradictory to the literature data: our results differ from those of Gondret *et al.* (*24*), but agree with those of Dalle Zotte *et al.* (*19*). In the protein content no marked differences were found due to genotype line. Statistically (p≤0.001), lower protein content in female compared to male animals and lower in older compared to younger animals was found. Reports can be found that with the increase in age at slaughter the protein content in back muscles either significantly decreases (*19*) or increases (*24*).

Lipid analyses

Intramuscular fat content

IMF content in rabbit lean meat differed according to genotype line, sex and age at slaughter (Table 5). The differences in the IMF content between different lines were significant (p≤0.05), the lowest IMF content was found in the line A. In male rabbits the IMF content was significantly lower compared to the female ones. It also increased with age. The IMF content (mean value of 36 observations ± standard deviation being (5.4±0.9) %) in the present study is not in accordance with findings of other researchers who determined a considerably lower fat content (*19,24–26*), which is probably due to the differences in tissue sampling. We emphasize that chemical analyses in the present study were made on average samples which were obtained by mixing the LL with hind leg and abdominal wall muscles of each rabbit carcass.

The composition of meat generally depends on the species (Table 6) and population of animals, location and manner of rearing as well as on their diet; for this reason the comparison of rabbit meat with meat of other species is neither straightforward nor easy. Nevertheless, the reports mention higher values for intramuscular fat content of beef compared to rabbit meat. Žlender *et al.* (*27*) determined the fat in six different muscles of Simmental and Brown bulls. The results ranked from 3.6 to 7.2 % of intramuscular fat.

Fatty acid composition

Generally speaking, some differences due to genotype, sex and animal age at slaughter were found in the fatty acid composition. Intramuscular lipids of rabbit meat in A line contain the larger proportion of PUFA than in other lines due to the highest content of linolenic (C18:2 *n*-6) acid. Higher content of palmitoleic (C16:1 *n*-7) acid was found in the experimental group of female compared to male and in 105-day-old rabbits compared to 93-day-old ones. On average, intramuscular lipids of rabbit meat contain a larger proportion (29.2 %) of pal-

Table 5. Chemical composition of rabbit meat (LL + hind leg + abdominal wall muscles) from animals of three genotype lines, two ages at slaughter and both sexes (*N*=36)

Effect of:		Genotype line				Sex			Age at slaughter/day		
Compound		A line	AC line	C line	Sign.	Male	Female	Sign.	93	105	Sign.
w(water)/%		71.6 ± 1.1	71.2 ± 0.7	71.6 ± 0.4	Ns	71.8 ± 0.8^a	71.2 ± 0.8^b	*	71.9 ± 0.7^a	71.1 ± 0.7^b	**
w(ash)/%		1.18 ± 0.06	1.16 ± 0.05	1.18 ± 0.03	Ns	1.19 ± 0.05^a	1.15 ± 0.04^b	*	1.20 ± 0.05^a	1.15 ± 0.03^b	***
w(protein)/%		22.0 ± 0.8	22.0 ± 0.5	22.0 ± 0.5	Ns	22.2 ± 0.6^a	21.7 ± 0.5^b	***	22.3 ± 0.5^a	21.6 ± 0.5^b	***
w(IMF)/%		5.0 ± 0.9^b	5.9 ± 1.0^a	5.4 ± 0.7^{ab}	*	5.2 ± 0.9^b	5.7 ± 0.9^a	*	5.2 ± 0.7^b	5.7 ± 1.1^a	*
w(cholesterol) (mg/100 g)		68.6 ± 7.3	67.6 ± 7.1	66.7 ± 10.4	Ns	63.7 ± 8.9^b	71.5 ± 5.1^a	**	68.1 ± 6.6	67.1 ± 9.7	Ns
w(FA)/%											
Lauric	C12:0	0.51 ± 0.65	0.65 ± 0.27	0.67 ± 0.87	Ns	0.67 ± 0.66	0.55 ± 0.61	Ns	0.81 ± 0.79	0.41 ± 0.32	Ns
Tridecanoic	C13:0	0.20 ± 0.21	0.20 ± 0.11	0.25 ± 0.34	Ns	0.22 ± 0.23	0.21 ± 0.25	Ns	0.29 ± 0.29	0.14 ± 0.14	Ns
Myristic	C14:0	2.82 ± 0.54	2.99 ± 0.38	2.74 ± 0.38	Ns	2.80 ± 0.45	2.90 ± 0.43	Ns	2.76 ± 0.36	2.94 ± 0.50	Ns
Myristoleic	C14:1 *n*-5	0.52 ± 0.27	0.56 ± 0.19	0.51 ± 0.17	Ns	0.50 ± 0.16	0.56 ± 0.25	Ns	0.48 ± 0.19	0.58 ± 0.22	Ns
Pentadecanoic	C15:0	0.65 ± 0.21	0.59 ± 0.12	0.61 ± 0.09	Ns	0.63 ± 0.17	0.60 ± 0.13	Ns	0.60 ± 0.13	0.63 ± 0.16	Ns
Palmitic	C16:0	29.8 ± 3.7	28.7 ± 3.4	29.1 ± 1.2	Ns	29.1 ± 2.3	29.3 ± 3.5	Ns	28.9 ± 1.9	29.5 ± 3.7	Ns
Palmitoleic	C16:1 *n*-7	6.06 ± 2.80	7.45 ± 2.79	7.18 ± 1.87	Ns	5.88 ± 1.49^b	7.91 ± 2.95^a	**	6.11 ± 1.88^b	7.69 ± 2.88^a	*
Margaric	C17:0	1.08 ± 1.33	0.60 ± 0.16	0.66 ± 0.05	Ns	0.65 ± 0.09	0.92 ± 1.10	Ns	0.66 ± 0.10	0.90 ± 1.10	Ns
Stearic	C18:0	5.87 ± 1.69	5.53 ± 1.56	5.90 ± 1.17	Ns	5.91 ± 1.14	5.62 ± 1.74	Ns	6.15 ± 1.35	5.38 ± 1.50	Ns
Trans-oleic	C18:1 *n*-9*t*	0.41 ± 0.20	0.41 ± 0.16	0.33 ± 0.13	Ns	0.37 ± 0.12	0.40 ± 0.20	Ns	0.40 ± 0.18	0.37 ± 0.15	Ns
Cis-oleic	C18:1 *n*-9*c*	23.8 ± 7.3	27.1 ± 4.4	27.2 ± 1.3	Ns	27.6 ± 2.2	24.5 ± 6.5	Ns	26.5 ± 2.3	25.6 ± 6.9	Ns
Linoleic	C18:2 *n*-6	24.5 ± 3.4^a	21.1 ± 2.6^b	21.4 ± 1.6^b	**	22.2 ± 2.3	22.5 ± 3.6	Ns	22.3 ± 3.0	22.4 ± 3.1	Ns
α-linolenic	C18:3 *n*-3	2.93 ± 0.32	2.68 ± 0.33	2.70 ± 0.18	Ns	2.76 ± 0.25	2.79 ± 0.36	Ns	2.74 ± 0.32	2.80 ± 0.29	Ns
Arahidic	C20:0	0.19 ± 0.09	0.19 ± 0.08	0.16 ± 0.06	Ns	0.17 ± 0.08	0.18 ± 0.07	Ns	0.18 ± 0.07	0.18 ± 0.08	Ns
Gadolenic	C20:1	0.30 ± 0.19	0.26 ± 0.12	0.25 ± 0.14	Ns	0.25 ± 0.13	0.30 ± 0.17	Ns	0.25 ± 0.14	0.30 ± 0.15	Ns
Behenic	C22:0	0.59 ± 0.59	0.34 ± 0.40	0.36 ± 0.37	Ns	0.41 ± 0.42	0.45 ± 0.52	Ns	0.60 ± 0.57^a	0.27 ± 0.25^b	*
SFA		41.7 ± 3.6	40.5 ± 4.9	40.5 ± 2.0	Ns	40.6 ± 2.9	41.2 ± 4.3	Ns	41.4 ± 2.5	40.4 ± 4.5	Ns
MUFA		31.1 ± 6.4	35.8 ± 5.4	35.5 ± 2.6	Ns	34.6 ± 3.3	33.6 ± 6.9	Ns	33.7 ± 3.6	34.6 ± 6.8	Ns
PUFA		27.4 ± 3.7^a	23.8 ± 2.9^b	24.1 ± 1.7^b	**	24.9 ± 2.5	25.3 ± 4.0	Ns	25.0 ± 3.3	25.2 ± 3.3	Ns
n-6/*n*-3		8.37 ± 0.65	7.88 ± 0.38	7.95 ± 0.45	Ns	8.06 ± 0.49	8.07 ± 0.60	Ns	8.11 ± 0.55	8.03 ± 0.54	Ns
P/S		0.66 ± 0.08	0.60 ± 0.11	0.60 ± 0.05	Ns	0.62 ± 0.08	0.62 ± 0.09	Ns	0.61 ± 0.09	0.63 ± 0.08	Ns
IA		0.72 ± 0.14	0.71 ± 0.14	0.69 ± 0.06	Ns	0.69 ± 0.08	0.72 ± 0.15	Ns	0.70 ± 0.07	0.71 ± 0.15	Ns

Mean values ± standard deviation in each group. *N* – number of observations. Means with a different superscript within groups differ significantly ($p \leq 0.05$). IMF – intramuscular fat content. SFA – saturated fatty acids. MUFA – monounsaturated fatty acids. PUFA – polyunsaturated fatty acids. P/S – PUFA/SFA. IA – index of atherogenicity = (C12 + 4 C14 + C16) / (PUFA + C18:1 + other MUFA) (*6*). *n*-6/*n*-3 – C18:2 *n*-6 / C18:3 *n*-3. Sign. – statistically not significant: Ns – $p > 0.05$; statistically significant: * $p \leq 0.05$ and ** $p \leq 0.01$; highly statistically significant: *** $p \leq 0.001$

Table 6. Cholesterol content and fatty acid composition of intramuscular fat from rabbit, red deer, beef, lamb and chicken meat of Slovenian origin

Parameter / Meat	Rabbit*	Red deer (*27*)	Beef (*28*)	Lamb (*29*)	Chicken (*30*)
Number of animals	36	16	16	48	50
w(SFA of total FA)/%	40.9 ± 3.6	38.4 ± 6.5	43.8 ± 4.8	51.3 ± 13.0	31.6 ± 1.1
w(MUFA of total FA)/%	34.1 ± 5.4	28.5 ± 5.1	47.3 ± 5.8	33.7 ± 16.5	48.0 ± 1.3
w(PUFA of total FA)/%	25.1 ± 5.4	31.7 ± 9.3	7.9 ± 2.5	15.0 ± 4.6	20.3 ± 1.5
P/S	0.62 ± 0.08	0.89 ± 0.40	0.18 ± 0.06	0.29 ± 0.07	0.64 ± 0.06
IA	0.70 ± 0.12	0.52 ± 0.27	0.51 ± 0.09	1.07 ± 0.64	0.42 ± 0.02
n-6/*n*-3	8.1 ± 0.5	2.9 ± 0.9	36.7 ± 14.3	6.6 ± 2.3	14.7 ± 0.5
w(cholesterol)/(mg/100 g)	67.6 ± 8.5	79.3 ± 13.8	74.3 ± 10.3	67.5 ± 19.4	–

Mean values ± standard deviation. * mean value of all our data. SFA – saturated fatty acids. MUFA – monounsaturated fatty acids. PUFA – polyunsaturated fatty acids. P/S – PUFA/SFA. IA – index of atherogenicity = (C12 + 4 C14 + C16) / (PUFA + C18:1 + other MUFA) (*6*). *n*-6/*n*-3 – C18:2 *n*-6 / C18:3 *n*-3

mitic (C16:0), 26.1 % of *cis*-oleic (C18:1 *n*-9*c*) and 22. 3 % of linoleic (C18:2 *n*-6) acid. Palmitoleic (C16:1 *n*-7, 6.9 %), stearic (C18:0, 5.8 %), miristic (C14:0, 2.9 %), α-linolenic (C18:3 *n*-3, 2.8 %), margaric (C17:0, 0.8 %), pentadecanoic (C15:0, 0.6 %), lauric (C12:0, 0.6 %), myristoleic (C14:1 *n*-5, 0.5 %), tridecanoic (C13:0, 0.5 %), behenic (C22:0, 0.4 %), *trans*-oleic (C18:1 *n*-9*t*, 0.4 %), gadolenic (C20:1, 0.3 %) and arachidic (C20:0, 0.2 %) acid are present as minor components.

The lower part of Table 5 gives the indices related to human health for the rabbit meat (LL + hind leg + abdominal wall muscles) from animals of three genotype lines, two ages at slaughter and both sexes. Average data from this study are compared to the data acquired in our laboratory on beef, red deer and chicken meat, and are presented in Table 6. The nutritional quality of fat has been evaluated in terms of the ratio of polyunsaturated:saturated fatty acids (P/S), the index of atherogenicity (IA), and the ratio of *n*-6/*n*-3 fatty acids. In a balanced diet, the recommended ratio for P/S is 0.4 or higher (*1*), IA as low as possible, and ratio *n*-6/*n*-3 less than 4 (*31*).

Meat is often considered rich in saturated fatty acid (SFA) and the relationship between SFA intake and cardiovascular diseases has been demonstrated by several epidemiological studies. However, fat content of rabbit muscles is rather low and not all fatty acids are saturated. This study showed that in the case of lean rabbit meat SFA represent 40.9 % of the total FA; the amount of polyunsaturated FA (PUFA) represents 25 % of the total FA, and is much higher than that found in beef, veal and pork (*2,27*). However, data about PUFA vary as to the muscle, selection and dietary manipulation (*2,8,26,32*). Due to the high content of linoleic acid (C18:2 *n*-6), the P/S ratio (0.62) in rabbit meat is higher than in pig, beef or veal, but lower than in red deer meat (Table 6). The determined index of atherogenicity (IA = 0.70), which is considered a rightful estimation for lipid nutritional quality, is also quite comparable with red deer meat and beef.

Our findings agree with those supporting the assessment that rabbit meat could be a very useful part of human diet. Rabbit meat, as Gandemer (*33*) emphasizes, excels in a relatively high content of PUFA and a relatively low fatty acid *n*-6/*n*-3 ratio in comparison with meat of other species. Data about the *n*-6/*n*-3 ratio from different sources (*8,26,32*) are quite different and vary from 2.95, in *longissimus dorsi* from a rabbit fed with dietary α-linolenic acid and supranutritional level of vitamin E (*31*), to higher values of about 11.6 for the hind leg (*24,26*). Our values 8.1±0.6 (Table 6) are even higher than the results published by Dalle Zotte (*2*) who reported a *n*-6/*n*-3 index of 6.7 for the rabbit meat.

Cholesterol content

From the data presented in Table 5 we can see that cholesterol content varied from 63.7 to 71.5 mg/100 g of fresh boneless rabbit meat (LL + hind leg + abdominal wall muscles); the average being 67.6 mg/100 g of fresh meat (FM). No marked differences due to genotype line or age at slaughter were found for the cholesterol content. Cholesterol content in male rabbits was significantly lower compared to similar data for female rabbits ($p \leq 0.01$). According to the statement of Dalle Zotte (*2*), rabbit meat contains the lowest levels of cholesterol among more popular meats. Our results disagree with her data and also with the data of other researchers who found a characteristically lower content of cholesterol in whole rabbit carcass (45 mg/100 g FM), hind leg (60 mg / 100 g FM) (*2*) and in the back muscles (from 45 to 48 mg/100 g FM (*24*); 57.5 mg/100 g FM (*34*)). These differences are probably due to the use of different analytical methods, different anatomical parts of the rabbits taken as representative samples and, last but not least, due to the evaluation of the analytical results. Data about the cholesterol content vary up to ±100 % (*35*).

Sensory properties

Genotype lines have not affected the main characteristics of rabbit meat, like smell, colour, tenderness, juiciness, mouth feeling, flavour and aftertaste of rabbit meat (Table 3). Generally, roasted rabbit meat in our study had a smell which was not intense enough (on the average 5.4 points from 7 points), a slightly pale colour (3.0 points), appropriate tenderness (5.4 points), but relatively poor juiciness (4.3 points) and mouth feeling (4.7 points), combined with a not enough intensive flavour (5.4 points) and quite expressive rabbit meat aftertaste (2.1 points). In this sense, we could consider that all genotype lines have some undesirable aroma characteristics, which could be and were detected by consumers.

The meat from 105-day-old rabbits had a better colour than that from 93-day-old rabbits, whereas other properties of the meat were not affected by the age at slaughter.

It is supposed that the flavour is mostly associated with the lipid content of the meat, but we did not find any explicitly strong correlation between the mentioned parameters (R=0.06). Furthermore, the overall assessment of juiciness in cooked samples was not significantly associated with variations in IMF content (R=0.14), which is in agreement with the results of Gondret *et al.* (*24*).

The aftertaste of rabbit meat was slightly related to the IMF in A line (R=0.32, P=0.32) and AC line (R=0.33, P=0.29), but it was not related to the IMF in C line (R=0.07, P=0.82). In all three genotype lines, a negative trend was found between the aftertaste and SFA (A line: R= –0.13, P=0.68; AC line: R= –0.35, P=0.27; and C line: R= –0.12, P=0.71). Similar trend was observed between the aftertaste and PUFA (A line: R= –0.43, P=0.16; AC line: R= –0.38, P=0.22; and C line: R= –0.22, P=0.16).

Conclusions

Generaly, age at slaughter (93 *vs.* 105 days) and sex (male *vs.* female) can and do affect the chemical composition (water, ash, protein, IMF and cholesterol content). Lines (A, AC, C) of SIKA genotype affect instrumentally measured cutting value across the fibres of roasted rabbit meat. Differences due to genotype lines and sex in instrumental colour and sensory profile of rabbit meat are coincidental. The meat from 105-day-old rabbits had a better sensorially evaluated colour ($p \leq 0.01$) than that from the 93-day-old rabbits; this finding was confirmed

also by instrumental measurements (the lowest L*, the highest a* values).

Ratio P/S (0.62), atherogenic index (0.70), ratio *n*-6/*n*-3 (8.07) and cholesterol content (67.6 mg/100 g) show that rabbit meat can be included into a balanced diet. Female samples contain more cholesterol than male ones (71.5 *vs*. 63.7 mg/100 g). Genotype line did not affect either the fatty acid profile or the content of cholesterol, but it did affect significantly the content of intramuscular fat (A line: 5.0 g/100 g; AC line: 5.9 g/100 g; and C line: 5.4 g/100 g).

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Utjecaj genotipskih rodova, starosti pri klanju i spola na sastav mesa kunića

Sažetak

Ispitan je kemijski sastav (voda, proteini, pepeo, intramuskularna mast, kolesterol, sastav masnih kiselina), senzorska svojstva te instrumentalno mjerene vrijednosti (boja i tekstura) tkiva nemasnog mesa kunića. Meso je potjecalo od tri različita roda genotipa SIKA (genotip A – ženska loza, C – muška loza, AC – hibridna loza oca i majke), a životinje oba spola pri klanju su bile stare 93 i 105 dana. Kunići su hranjeni komercijalnom hranom *ad libitum*. Od 36 životinja skupljeni su leđni mišići (*m. longissimus lumborum*), zatim mišići s trbušne stijenke i stražnjih nogu. Meso kunića prosječno sadržava 71,5 % vode, 22,0 % proteina, 1,17 % pepela, 5,4 % intramuskularne masti, 67,6 mg kolesterola/100 g svježeg mesa, a od masnih kiselina 34,1 % čine mononezasićene, 25,1 % polinezasićene i 40,9 % zasićene masne kiseline. Prema masenom omjeru nezasićenih i zasićenih masnih kiselina (0,62), aterogenog indeksa (0,70), masenog omjera *n*-6/*n*-3 (8,1) i količine kolesterola vidi se da se meso kunića može i treba koristiti u uravnoteženoj prehrani. Meso ženki kunića sadržava više intramuskularne masti i kolesterola u usporedbi s mužjacima (5,7 prema 5,2 g intramuskularne masti/100 g; $p \leq 0,05$; 71,5 prema 63,7 mg kolesterola/100 g; $p \leq 0,01$). Genotipska loza ne utječe na sastav masnih kiselina niti na količinu kolesterola, ali bitno utječe na intramuskularnu mast (A loza 5,0 g/100 g; AC loza 5,9 g/100 g; C loza 5,4 g/100 g; $p \leq 0,05$), kao i na vrijednosti prerezivanja vlakana (aparat Instron; A loza 43 N; AC loza 38 N; C loza 42 N; $p \leq 0,05$). Meso 105 dana starih kunića sadržava više intramuskularne masti (5,7 prema 5,2 g/100 g; $p \leq 0,05$), a prema izgledu je tamnije i crvenije (prosudba na osnovi senzorske analize i instrumentalno mjerenih vrijednosti L* i a*; $p \leq 0,01$) u usporedbi s 93 dana starim kunićima.