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The application of the near-infrared spectroscopic (NIRS) technique in assessment of chemical composition of the lamb meat*

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The aim of the study was to analyze the basic chemical composition (water, protein, collagen and fat content) of the lamb meat, using Food Scan analyzer. The obtained results were compared with the determinations, received by the reference methods in accredited laboratories. The studies included 110 lambs (rams) of four genotypic groups: two native breeds (Polish Heath Sheep and Żelazna Sheep) and two crossbred of the mentioned breeds with meat breed Berrichonne du Cher (WOBER and POBER). The body weight of the animals was ca. 40 kg. The research material contained the samples of *m. longissimus dorsi* of ca. 250 g. The meat of Polish Heath Sheep contained the highest quantities of collagen and protein (1.91% and 22.17%, respectively) and the lowest level of fat (3.51%). Any effect of genotype on the water content in meat was not found. The results, obtained by the reference and spectroscopic methods were comparable. The highest correlation coefficients were recorded for fat (0.964) and protein (0.626). In the case of the remaining parameters, lower positive correlations were found.

KEY WORDS: near-infrared (NIR) / lamb meat / chemical composition of the meat / quality assessment meat

Spectroscopy is a field of science comprising a series of methods, in which matter is tested using various radiation types. It is also a science on the formation and interpretation of spectra. Infrared (IR) spectroscopy is a variant of electromagnetic spectrum spectroscopy, which scope covers near, mid and far infrared radiation [16]. ASTM International reports that the S region within the wavelength range of 780-2526 nm, corresponding to the frequencies ranging from 12 820 to 3959 cm^{-1}, is found close to the region of visible light [1, 16]. In recent years near infrared spectroscopy has become an important technique, providing sufficient records of information on the structure of chemical compounds [1].

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Consumers purchase raw meat most frequently based on its sensory attributes (colour, taste) and the price of the product; however, they are willing to pay more for a superior quality product characterised by a unique nutritive value [4]. Systematically amended nutritional guidelines and increased consumer awareness impose on producers of animal origin food, including lamb, the obligation to satisfy increasingly stringent quality requirements and consumer expectations [6]. Contemporary consumers search for safe food with reduced fat and cholesterol contents [5, 9]. Lamb quality determining consumer acceptability depends first of all on its physico-chemical properties, nutritive value, including fat content and the fatty acid profile, as well as sensory attributes. Quality of lamb meat is influenced by many significant factors: breed, sex, the environment, management system [8, 15].

Lamb meat contains a large number of various nutrients and compounds. The most important of these include water (approx. 69%), crude protein (approx. 18%), fat (approx. 12%), carbohydrates (approx. 1%) and minerals (approx. 1%). Studies concerning meat quality are becoming increasingly objective thanks to the improvement in the techniques used in chemical and physical assays. The quality standard, assessed in view of the requirements of a given market segment, is changing under the influence of producers, the industry, trade and consumers. As it is necessary to provide a uniform product it is crucial to identify factors affecting its quality [5]. Within the last several decades many instrumental non-invasive techniques have been tested and implemented in the assessment of food quality. Among these methods near infrared spectroscopy (NIRS) is most popular, mainly thanks to its rapidity, reduced costs of analyses and simultaneous testing of many attributes [7].

The aim of this study was to analyse accuracy of determinations for basic chemical components in lamb (contents of fat, protein, collagen and water) using advanced spectroscopic techniques.

Material and methods

The animal material came from the Agricultural Experimental Station in Żelazna, belonging to the Warsaw University of Life Sciences SGGW, and it comprised 110 lambs (tup lambs) from 4 groups. The groups consisted of two native breeds, i.e. Polish Heath Sheep (Wrzosówka, n=22) and the Żelazna Sheep (n=37), and crosses of these breeds (ewes) with the French mutton breed Berrichonne du Cher (rams), i.e. WROBER (Wrzosówka x Berrichonne du Cher, n=33) and POBER (Żelazna Sheep x Berrichonne du Cher, n=18). Lambs were kept in the indoor housing system. Maternal nursing lasted until day 100 of life. Since the second week of life, apart from maternal milk *ad libitum* lambs were also fed forage *ad libitum*. Lambs received meadow hay as well as clipped oats, which was later replaced by concentrates. After weaning lambs were fed following the respective standards [13], using forage produced on the farm and forage fed before weaning (meadow hay and concentrates produced on the farm, i.e. a mixture of ground oat, barley and triticale).

Lambs were slaughtered according to the Council Regulation (EC) no. 1099/2009 of 24 September 2009 (Official Journal of the European Union of 18.11.2009, L 303/1). Tup lambs were slaughtered at a body weight of 40 kg (±1.5 kg). Mean age of lambs at slau-

ghter was approx. 11 months, while the required body weight was reached the earliest by Żelazna Sheep (approx. 9 months) and POBER (approx. 10 months). Polish Heath Sheep were reared the longest, i.e. over 13 months, while WROBER crossbreds were reared for approx. 11 months. Carcasses were cooled at +4°C for 24 h and next they were weighed and dissected into half-carcasses. Right half-carcasses were weighed and dissected into primal cuts according to Nawara et al. [11]. Qualitative analyses were conducted on samples of the rump – a section of the longissimus dorsi muscle (*m. longissimus dorsi – m.l.d.*). Each sample of approx. 250 g was placed in a sterile, sealed zipper bag and stored at –20°C.

The chemical composition of meat was analysed to determine contents of water, dry matter, protein, fat and collagen using two methods. Standard laboratory analyses were performed at accredited laboratories, while the other method involved near infrared spectroscopy (NIRS). Water content was determined at the laboratory of the Sheep and Goat Breeding Division, the Warsaw University of Life Sciences SGGW using the oven drying method according to PN-ISO 1442: 2000. Crude protein and fat were assayed at the Analytical Centre, SGGW in Warsaw. Crude protein was determined according to Kjeldahl applying the N×6.25 factor value – Analytical Procedure 11 version 5 of 07.03.2012, while fat was assayed according to Soxhlet using n-hexane as a solvent – Analytical Procedure 19 version 5 of 18.06.2007. Determination of total collagen content was performed at the laboratory of J.S. Hamilton Poland Sp. z o.o. based on calculations of hydroxyproline content, applying the conversion factor of 8 in accordance with the Regulation of the Minister of Agriculture and Rural Development of 10 July 2007 § 8.1.4. (the Journal of Laws Dziennik Ustaw of 2007 no. 137, item 966).

The analysis of meat chemical composition by near infrared spectroscopy (NIRS) consisted in the homogenisation of a 200g meat sample in a DITO K35 cutter by Electrolux and placing the homogenised sample in the cuvette of a FoodScan analyser using near infrared transmission within 850-1050 nm and equipped with the ANN calibration (developed using an artificial neural network model). Analyses were conducted by entering the number of measurements in the sample in the computer programme and the programme automatically calculated the mean and gave the result.

The results were analysed statistically using the least squares method. Calculations were performed with the IMB SPSS Statistics 21.0 programme, assessing the effect of genotype on estimated parameters of the chemical composition. Finally, the two analytical methods were compared.

Results and discussion

Table 1 presents measurement results for chemical components of meat (water, crude protein, fat and collagen) obtained using the reference methods and using near infrared spectroscopy (NIRS). The highest water content was recorded in meat of Żelazna Sheep (74.13%). In the laboratory analysis the differences between mean water content in meat of the analysed group of lambs were statistically non-significant. In turn, the near infrared method showed significant differences between water content in meat of Żelazna tup lambs and WROBER crosses (Table 1).

Table 1

The chemical composition of lamb meat of four genotypes obtained in the reference laboratory and using the FoodScan analyzer

Genotype		n	Water_CA (%)	Water_FS (%)	Crude protein_CA (%)	Crude protein_FS (%)	Collagen_CA (%)	Collagen_FS (%)	Fat_CA (%)	Fat_FS (%)
POBER	x	18	73.40	73.30	21.14^{d}	22.07^{d}	1.67	1.60^{e}	4.55^{d}	4.84
	SE		1.14	0.36	0.19	0.18	0.12	0.05	0.38	0.37
Żelazna Sheep	x	37	74.13	73.51^{e}	20.88^{cd}	21.57^{d}	1.68	1.55^{e}	4.57^{d}	4.97^{d}
	SE		0.76	0.24	0.13	0.12	0.08	0.03	0.25	0.25
WROBER	x	33	73.26	72.64^{b}	21.48^{bd}	22.15^{d}	1.88	1.75^{abd}	4.79^{d}	5.02^{d}
	SE		0.80	0.25	0.14	0.12	0.08	0.03	0.27	0.26
Polish Heath Sheep	x	22	73.76	73.12	22.17^{abc}	22.92^{abc}	1.91	1.61^{c}	3.51^{abc}	4.09^{bc}
	SE		1.02	0,32	0.17	0.16	0.11	0.04	0.34	0.33

POBER – crossbreds Żelazna Sheep x Berrichonne du Cher
WROBER – crossbreds Polish Heath Sheep x Berrichonne du Cher
n – number of samples
Water_CA, crude protein_CA, collagen_CA, fat_CA – analysis of the reference method
Water_FS, crude protein_FS, collagen_FS, fat_FS – analysis by FoodScan method

The highest protein content was recorded in meat of the Polish Heath Sheep: 22.17% (the reference method) and 22.92% (spectroscopy). In turn, in the other native breed, i.e. Żelazna breed, it was 20.88% protein (the reference method) and 21.57% protein (spectroscopy). Lambs of the Żelazna Sheep were characterised by the lowest protein content among the tested genotypes. When comparing the crossbreds a slightly higher protein content was recorded in meat of WROBER lambs. These differences proved to be statistically significant (Table 1). In meat of mountain sheep breeds crude protein content is found within the range of 20.51-20.86% [14], while in English mutton breeds it is approx. 19% [9].

Meat of the WROBER crossbreds and the Heath sheep lambs was characterised by the highest collagen content both in the case of the reference results and the FoodScan data. In the laboratory method differences in recorded collagen contents between individual genotypes were not statistically significant. According to NIRS collagen content in meat of the WROBER crossbreds differed statistically significantly from that in the other genotypes (Table 1). These differences may result from the fact that growth in lambs of the Polish Heath Sheep and its crossbreds until a body weight of 40 kg took longer than in the other lambs. Using standard methods Komprda et al. [8] determined collagen content in meat of mutton sheep breeds at approx. 2.58%. In turn, a study by Martínez-Cerezo et al. [10] showed an effect of breed on collagen content, which is confirmed by the presented results.

Fat content in lamb meat varies depending on the breed and age of the animal [5]. Both analytical methods showed the greatest fat content in meat of the WROBER crossbreds (Table 1). Significantly the lowest fat content was recorded in meat of the Polish Heath Sheep. This results from the fact that it is a breed raised for pelts, not a mutton breed. Thanks to the exceptional high eating value of its meat it is used increasingly often either for meat purpose or for crossing with mutton breeds. In lambs of mountain sheep slaughtered at the age of 100 days (approx. 17 kg) fat content is approx. 2.1%, while in lambs aged 200 days (approx. 24 kg body weight) it is approx. 2.8% [14]. The mutton breed Berrichonne du Cher is characterised by fat content of approx. 2.12% at a slaughter weight of 35 kg [12]. Similar results were recorded by Komprda et al. [8] in their study on English mutton breeds.

When analysing the relationship between the results of assayed chemical components using the two different methods the effect of genotype on individual parameters was disregarded. Standard error (SE) indicates variability of the tested samples. It may be observed that this variability is more evident in the results provided by the laboratory methods. The greatest error and scatter of the laboratory data may be observed in all the groups when analysing collagen and protein contents (Table 1). For fat the results of both methods are most consistent, which is confirmed by almost identical SE and the results of their correlations (Tables 1 and 2).

When comparing the two analytical methods the strength of their relationships was verified by calculating correlation coefficients (Table 2). Results of statistical analysis and calculated correlation coefficients for all the parameters showed a positive correlation. The strongest dependence was found in the case of fat (0.964), followed by protein (0.626). The lowest correlation values were found for collagen (0.400) and water contents (0.351).

For a more detailed analysis coefficients of determination (R^2) were calculated. Their value shows what percentage of variation in the dependent (explained) variable is explained

Table 2
The correlation coefficients for the tested components of the meat

		Collagen_CA	Crude protein_CA	Fat_CA	Water_CA
Collagen_FS	correlation	**0.400****	0.282**	0.281**	–0.091
	significance	0.000	0.003	0.003	0.342
Crude protein_FS	correlation	0.020	**0.626**	–0.409	–0.088
	significance	0.836	0.000	0.000	0.359
Fat_FS	correlation	0.208*	–0.073	**0.964**	–0.254
	significance	0.030	0.446	0.000	0.007
Water_FS	correlation	–0.314	–0.310	–0.787	**0.351**
	significance	0.001	0.001	0.000	0.000

**The significance level 0.01 (both sides)
*The significance level 0.05 (both sides)

by the independent variable. Here results of the laboratory method were the explanatory variable, while r=those provided by the FoodScan analyser were the independent variable. The highest R^2 was obtained in the analyses of fat and protein (0.93 and 0.39, respectively), which indicates that both these methods are comparable. For the other parameters markedly lower coefficients of determination were obtained, which suggests the need for further studies and fine-tuning of the methodology of the analyses (Table 3).

Table 3
Coefficients of determination (R^2) for the tested components of the meat

Parameter		R^2
Pair 1	collagen_CA (%)	0.16
	collagen_FS (%)	
Pair 2	protein_CA (%)	0.39
	protein_FS (%)	
Pair 3	fat_CA (%)	0.93
	fat_FS (%)	
Pair 4	water_CA (%)	0.12
	water_FS (%)	

Applicability of the potential of visible light and near infrared (NIRS) in meat analyses has been relatively extensively investigated and discussed. Andres et al. [2] in their study applied spectroscopy to determine sensory attributes affecting quality of lamb meat and compared contents of water and fat in meat samples as assayed using chemical methods and using spectroscopy. In the opinion of the authors [2] spectroscopy may be applied for precise determination of amounts of contained water (R^2=0.84) and fat (R^2=0.674).

Summing up it may be stated that spectroscopic methods using near infrared (NIRS) provide values of determined chemical components in lamb meat which are comparable to those assayed by the reference methods. The high correlation coefficients and coefficients of determination obtained in this study indicate that the FoodScan analyser may be used to determine fat content in lamb meat instead of the reference Soxhlet method. It was shown that meat of the Polish Heath Sheep contained significantly the greatest amounts of protein and the lowest amounts of fat, while meat of its crosses with Berrichonne du Cher (WROBER) contained the highest amount of collagen. These results justify the advisability of further studies on the subject.

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