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The analysis of pig carcass classification in Slovakia

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Abstract: In the last decade, the pig sector in Slovakia has been changing continuously, especially in regard to the proportion of pigs coming from foreign breeding programs. These changes lead to changes in carcass characteristics and to a change in the distribution of carcasses within the classes of the Union scale for the classification of pig carcasses. Therefore, this study was undertaken to analyse the actual state of pig carcass classification in the Slovak Republic and to investigate the needs of updating the equations for the classification methods and possible steps to improve the quality of pork produced within the country. Results showed that an increased number of pig carcasses originated from Danish breeding program, and also from the Czech Republic and Poland. When compared to carcasses in 2009, these changes resulted in lower backfat thickness and higher muscle thickness of the *longissimus dorsi* muscle and thus higher lean meat content of carcasses. This results in a higher number of carcasses classified in the S and E classes. Slight differences between two instrumental classification methods were calculated. The study showed the need for updating the equations for classification methods, and also suggested possible further steps in order to improve the quality of pork.

Keywords: carcass quality; SEUROP; grading; lean meat content; backfat thickness; muscle thickness

The pig breeding sector in Slovakia has been changing continuously in the last decades. Statistical office of the Slovak Republic reported a decrease of the total number of pigs in the period 2015–2019 from 633 116 to 589 228 and a slight decrease of sows from 38 122 to 37 713 in the country. These changes include not only a decrease of the number of animals but also changes in the ownership and consequent changes in management and genotypes of animals. These changes lead to different pig carcass types and thus affect the classification process in slaughterhouses (Font-i-Furnols et al. 2016). Consequently, classification methods need to be updated to reflect the actual state of pig carcass characteristics in slaughterhouses.

The classification of pig carcasses in Slovakia is laid down by Regulation (EU) No. 1308/2013, Commission Delegated Regulation (EU) 2017/1182 and national Edict No. 205/2007. Applying the Union scale for the classification of pigs (SEUROP) is compulsory in all slaughterhouses in the country. Based on the Commission Decision 2009/622/EC and in accordance with the Regulation (EC) No. 1234/2007 three methods for grading pig carcasses were authorized in Slovakia in 2009. These include two-point (TP) method, Fat-O-Meater (FOM)

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and UltraFOM 300 (UFOM). In practice, FOM and UFOM instruments are used in big slaughterhouses, while the TP method is used as an alternative in the case of unexpected problems with FOM and UFOM methods and in small slaughterhouses (up to 100 carcasses per week). Both instruments (FOM, UFOM) use only the thickness measurements from the *longissimus dorsi* site which need not reflect the real commercial value of the carcass (Marcoux et al. 2007; Knecht et al. 2016). Earlier experiments with computed tomography (Picouet et al. 2010) and recent developments in automated classification instruments allow such predictions of primal cuts (Janiszewski et al. 2019). Actual selection for low backfat thickness also negatively affects the quality of pork (Nakev and Popova 2019), and thus it affects the sales of meat in times of higher consumer demand for quality products.

The aim of this paper was to analyse pig carcass characteristics and distribution in slaughterhouses in Slovakia and their changes over time. Special emphasis was laid on the part of carcasses classified within the Union scale for the classification of pigs (SEUROP) and comparison of the two instruments used in the classification of pigs in order to analyse the need of updating the equations for classification methods and to discuss possible ways of improving the quality of pig carcasses in Slovakia.

MATERIAL AND METHODS

Commercial data from six major slaughterhouses (weekly capacity more than 100 pigs) in Slovakia from 2015 to 2019 were used in the present study. Five slaughterhouses used FOM instrument (RMSEP = 1.703 1) and one used UFOM instrument (RMSEP = 1.560 3). All slaughterhouses used the TP method as an alternative in the case of problems with instrument. Data from TP were not included in the dataset. Overall statistics on total slaughters and distribution of carcasses in the country were obtained from publicly available sources. Data were processed and analysed using the SAS software v9.4 (SAS University Edition). In Table 1 the representativeness of the data with regard to the total number of slaughters in the country (as reported by Eurostat 2020) is presented.

Since the emphasis of the study was laid on the part of carcasses classified within the Union scale for the classification of pigs (SEUROP), other classes were excluded from the study. It is no surprise that 97.7% of the classified carcasses were classified within SEUROP classes. Light pigs with carcass weight below 60 kg and heavy pigs with carcass weight above 120 kg as well as sows and other minor categories represented only a negligible share of all slaughters.

Data on subcutaneous backfat thickness (BT) and muscle thickness (MT) measured at a site between the second and the third last rib, 70 mm beside the midline of the split line, by both methods were obtained. Lean meat content (LMC) was calculated within the classification process according to the equations laid down in the Commission Decision 2009/622/EC (EC 2009) and the corresponding classification class was assigned.

The prediction of LMC and factors affecting classification methods were analysed using GLM in the SAS software v9.4 (SAS University Edition). The analysis of LMC prediction was applied on the whole dataset (1 915 463 records) using simple linear regression models with BT, MT or their combination.

In order to analyse the factors affecting the LMC prediction only part of the data was used. Since the effects of classification method (CM) and slaughterhouse (SH) were partly overlapping, results could have been biased and the use of both factors in the model analysis would result in a non-estimable factor. Therefore, only data from five slaughterhouses using FOM instrument were used (1 826 731 records). The sex of the animals is not recorded during slaughter and thus this effect could not be analysed. In this respect some authors (Mohrmann et al. 2006; Bahelka et al. 2007) reported different lean meat content in gilts and barrows, however studies by Krska et al. (2002) and Engel et al. (2012) reported that even if the effect of sex is significant, there will be only a negligible gain in respect to RMSEP with using separate equations for the sexes. Also, the genotype of the

Table 1. Number of carcasses and representativeness (%) of dataset

Year	Study	Total slaughters	Representativeness
2015	294 365	496 790	59.25
2016	348 852	529 370	65.90
2017	402 009	534 800	75.17
2018	485 990	620 590	78.31
2019	428 512	676 790	63.32

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individual animals was not available, but some estimation could be applied to indirectly analyse this effect. Data on supplier included producers and traders. Based on the producer/trader information the information on the prevailing genotype of animals or at least the breeding program was estimated (Table 2) and used in the statistical models as origin of animals. In the case of Slovak producers with no foreign breeding program, the prevailing genotypes of fatteners were obtained. In the dam position Large White × Landrace crossbreds were prevalent and in the sire position different crosses of Yorkshire × Pietrain, Hampshire × Pietrain, or purebred Pietrain and purebred Duroc boars were prevalent.

Information on the operator was not available either. However, the effect of slaughterhouse includes the averaged effect of operator as well as the effect of the slaughterhouse environment. A general equation was used:

$$Y = F + CW + e \quad (1)$$

where:
Y – one of the observed traits (lean meat content, backfat thickness, muscle thickness);
F – one or two fixed effects (slaughterhouse, origin of animals);
CW – possible regression on carcass weight;
e – random residual effect.

The commercial data did not allow using both instruments on the same carcass and thus comparing their accuracy directly. In order to have the instruments used on similar animals and to analyse differences between the methods in predicting BT, MT and LMC the group of DK animals (992 305 records) and general equation were used:

$$Y = F + CW + e \quad (2)$$

where:
Y – one of the observed traits (lean meat content, backfat thickness, muscle thickness);
F – fixed effect of classification method;
CW – possible regression on carcass weight;
e – random residual effect.

Since the effects of CM and SH were overlapping, SH was not included in the model to prevent non-estimable factor result.

Table 2. Origin of animals

	Description
CZ	Producers/suppliers from the Czech Republic
DK	Producers/suppliers within Slovakia using animals from Danish breeding program
DU	Producers/suppliers within Slovakia using animals from Dutch breeding program
HU	Producers/suppliers from Hungary
NL	Producers/suppliers from the Netherlands
PL	Producers/suppliers from Poland
SK	Producers from Slovakia
UK	Producers/suppliers within Slovakia using animals from British breeding program
XX	No detailed information on producer/supplier of animals

RESULTS AND DISCUSSION

Distribution of carcasses

Most of the carcasses were classified within two classes (S and E) during the studied period, with more than 73% of carcasses classified within the S class each year. On the other hand, only a small portion of carcasses was classified within the last three classes (R, O, P). Only small changes of carcass distribution over the studied period could be explained due to a short time span, and also by the fact that the major changes in the population of pigs occurred before the studied period. The pig sector in Slovakia has been changing in the last decades. Production of breeding animals has been decreasing in the country while the use of final hybrids, especially from international breeding programs, has been increasing. This trend was proved by the fact that more than 50% of all slaughters in the studied period and classified within SEUROP classes were from suppliers and producers using animals from the Danish (DK) breeding program. The trends of slaughters of animals from abroad, especially from the Czech Republic (CZ) and Poland (PL), were increasing in the studied period while the number of slaughtered animals with Slovak origin was decreasing. This can be partially explained by the opposite situation when Slovak producers use services of abattoirs in neighbouring countries like Hungary (HU) and Poland. Results also showed a different distribution of carcasses within the SEUROP classes according to the origin of animals. While the portion

https://doi.org/10.17221/231/2020-CJAS

Table 3. Change of distribution of carcasses according to SEUROP class

Year		S	E	U	R	O	P
2009 (source: ATIS 2009)	*n*	39 292	124 816	35 525	5 242	606	177
	%	19.11	60.69	17.27	2.55	0.29	0.09
2019 (source: ATIS 2019)	*n*	213 139	56 755	11 199	1 842	484	55
	%	75.19	20.02	3.95	0.65	0.17	0.02
2019 (source: recent study)	*n*	342 672	67 635	8 791	827	93	19
	%	79.97	15.78	2.05	0.19	0.02	0.00

of SK carcasses classified in S and E class was almost equal (43.96% versus 41.54%), higher portions of CZ (73.30%), PL (73.34%) and DK (89.20%) carcasses were classified in the S class. When adding the S and E classes together, portions of more than 94% were found in DK carcasses, but also in CZ, HU, PL, Dutch (DU and NL) and British (UK) carcasses. On the other hand, more than 14% of SK carcasses were classified in other classes than S and E.

More visible changes in the distribution of carcasses within the SEUROP classes over a longer period are presented in Table 3, where the dataset from our study is compared with data provided by Agricultural Paying Agency (ATIS 2019). It can be seen that the distribution of carcasses in the SEUROP classes changed a lot during the period of ten years. While in 2009, when the classification methods were adopted, the portions of carcasses in classes S and E were approximately 20% and 60%, in 2019 the proportions changed to 75% and 20%, respectively. Such changes are witnessed in many European countries, although some of them reported a slight decrease of LMC in the last years (Jansons et al. 2016). Rapid change in the distribution of carcasses may also be attributed to the change of the equation for the lean meat content calculation (Kusec et al. 2009). Although the formula was revised in 2006 by Commission Regulation (EC) No. 1197/2006, new formulas for instruments reflecting this new scaling factor in Slovakia were approved in August 2009 and thus for the longer part of the year carcasses were classified according to old equations. Nowadays, the changed distribution and origin of carcasses might suggest the need for updating the equations for carcass classification methods in the country. Moreover, the changes in distribution, especially concentration of carcasses in two classes (S and E), might be a signal for the subdivision of pig carcass classification classes into subclasses, which is allowed by Commission Delegated Regulation (EU) 2017/1182. This especially applies to the S class, where more than 14% of the classified carcasses had LMC higher than 65% in 2015–2018 and more than 20% of the classified carcasses in the last year of the studied period. This situation also allows to think about improving the classification not only based on the LMC but putting emphasis on the individual cuts of the carcass and including other traits like the quality of meat in order to better reflect the commercial value of carcasses.

Different distributions according to slaughterhouses were observed (Table 4). This was due to different suppliers of animals. In some cases, the geographical location (vicinity of the borderline) of a slaughterhouse might help the slaughterhouse to prefer suppliers from neighbouring countries (CZ, HU, PL).

Prediction of lean meat content

The prediction of LMC highly depends on the backfat thickness in both classification methods. Higher portions of explained variability of LMC by models including only BT measurement compared to models predicting LMC including only MT measurement were calculated (Table 5). When comparing models using both measurements, the FOM instrument performed better com-

Table 4. Distribution of carcasses (%) according to SEUROP class and slaughterhouse 1–6

Slaughterhouse	S	E	U	R	O	P
1	91.59	8.19	0.21	0.01		
2	33.56	46.45	17.59	2.08	0.20	0.12
3	94.47	5.35	0.18	0.003	0.001	0.001
4	66.97	29.30	3.38	0.28	0.05	0.02
5	81.55	16.68	1.72	0.04	0.003	
6	88.77	10.75	0.46	0.02	0.001	0.002

https://doi.org/10.17221/231/2020-CJAS

pared to UFOM. These findings are similar to those reported by Kvapilik et al. (2009). Better prediction of LMC using FOM may be due to the higher precision of backfat measurement with an optical instrument compared to the ultrasonic one (Pomar and Macroux 2005).

Due to limited information from the commercial data, only the factors of slaughterhouse and animal origin could be analysed (Table 6). The model using only the effect of animal origin explained 12% of BT and LMC variability, but only negligible variability of MT. This shows that the origin of animals (including their genotype) is more manifested in BT, and consequently in LMC, than in MT. The model including only the effect of slaughterhouse explained a similar portion of BT and LMC variability like the model with the origin and it also explained 16% of MT variability. These findings show there were differences in animal between the slaughterhouses, which led to different distributions of carcasses (Table 4). It also shows there are differences in slaughterhouses, which can result from different operators and also from different environment of a slaughterhouse. When models included both effects and also the carcass weight was added as regression, no major improvement was observed in R^2. These findings suggest that the preparation of the authorization trial will have to take into account the fact of different distributions and suppliers of carcasses between slaughterhouses. Emphasis should be laid on the origin of carcasses, not on the geographical distribution.

Even though the instruments measure carcass characteristics at the same site, different results may be obtained due to different principles of measurements (reflectance in FOM and ultrasound in UFOM). Lisiak et al. (2012) reported different backfat thickness and muscle thickness measured on the same carcasses with FOM and UFOM instruments. Also, Fortin et al. (2004) reported different depths measured at the same site of the carcass with Hennessy grading probe 2 and UFOM with higher difference observed in muscle depths. In our recent study the instruments were used on different carcasses and therefore larger differences might be expected. In order to minimize differences between the carcasses and to improve the objectivity of comparison of the methods, differences between the methods in predicting the carcass characteristics were studied on carcasses coming only from a prevalent breeding program. The model including carcass weight (CW) and CM explained 12% of BT (Table 7). The difference in BT between the methods was 1.16 mm. This difference is higher than a difference of 0.84 mm reported by Kvapilik et al. (2009) and it seems even higher when compared to the systematic error of measurement (0.7 mm) reported by Olsen et al. (2007). The difference in MT between the methods was 1.74 mm. Finally, the difference in predicted LMC was 2.78% favouring the FOM instrument. Taking into account that a difference of 2% LMC may be attributed to uncertainties explained by differences between operators, environments and others uncertainties which cannot be explained (Olsen et al. 2007), there was 0.78% LMC that could be explained by detailed treatment of the operator effect or could be attributed to differences between the two methods.

Table 5. Prediction of lean meat content according to classification method

	FOM		UFOM	
	R^2	RMSE	R^2	RMSE
Model 1	0.78***	1.33	0.86***	1.37
Model 2	0.31***	2.36	0.04***	3.57
Model 3	0.99***	0.22	0.90***	1.12

FOM = Fat-O-Meater; Model 1 = includes only effect of backfat thickness; Model 2 = includes only effect of muscle thickness; Model 3 = includes both effects of backfat thickness and muscle thickness; UFOM = Ultra Fat-O-Meater 300

***$P < 0.001$

Table 6. Factors affecting lean meat content (LMC) prediction using Fat-O-Meater

	LMC		BT		MT	
	R^2	RMSE	R^2	RMSE	R^2	RMSE
Model 4	0.12***	2.67	0.12***	3.57	0.02***	8.56
Model 5	0.15***	2.62	0.10***	3.60	0.16***	7.93
Model 6	0.20***	2.54	0.18***	3.47	0.16***	7.92
Model 7	0.21***	2.52	0.27***	3.25	0.28***	7.35

BT = backfat thickness; Model 4 = includes only effect of origin; Model 5 = includes only effect of slaughterhouse; Model 6 = includes effects of origin and slaughterhouse; Model 7 = includes effects origin and slaughterhouse and carcass weight; MT = muscle thickness

***$P < 0.001$

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Table 7. Least squares means of classification methods

	R^2	RMSE	FOM (n = 965 799)		UFOM (n = 26 506)		LSM difference
			LSM	SD	LSM	SD	
BT (mm)	0.12***	2.79	12.53	0.003	13.69	0.02	***
MT (mm)	0.13***	7.90	62.99	0.01	61.25	0.05	***
LMC1 (%)	0.07***	2.34	62.96	0.002	59.20	0.01	***
LMC2 (%)	0.98***	0.32	62.93	0.000 3	60.15	0.002	***

BT = model includes classification method and carcass weight; FOM = Fat-O-Meater; LMC1 = model includes carcass weight and classification method; LMC2 = model includes carcass weight, backfat thickness, muscle thickness and classification method; MT = model includes classification method and carcass weight; UFOM = Ultra Fat-O-Meater 300
***P < 0.001

Carcass characteristics

The measured characteristics of carcasses according to SEUROP classification classes are summarized in Table 8. Obvious trends were observed. While the backfat thickness increased from S class to P class, the muscle thickness decreased in the same direction. In this regard Nakev and Popova (2019) reported that a decreasing trend of fat in carcasses is related with consequent problems of selling some valuable cuts. Some authors (Bahelka et al. 2007) already called for the inclusion of intramuscular fat content into breeding programs of pigs. Problems with low backfat thickness and intramuscular content can be partially avoided by including local breeds into breeding programs that can improve the quality of pork. Many studies in the past, but also present studies, showed higher intramuscular fat content, more intensive colour, higher tenderness and lower water loss in local breeds (Almeida et al. 2018; Martins et al. 2020). Another commonly known approach is the preference of Duroc sires to improve the quality of pork, especially the visual characteristics like colour and marbling (Lindahl et al. 2006; Latorre et al. 2009; Lowell et al. 2019). Both approaches, however, might be connected with the decrease of LMC in the carcasses.

Table 8. Carcass characteristics according to SEUROP class

	S	E	U	R	O	P
BT (mm)	12.38	18.03	23.89	30.32	38.61	45.24
MT (mm)	63.76	56.92	55.17	52.14	47.83	44.21
CW (kg)	89.71	92.14	95.40	98.39	97.16	96.78
LW (kg)	113.04	116.10	120.21	123.97	122.43	121.95
LMC (%)	63.12	58.23	53.38	48.33	42.91	35.22

BT = backfat thickness; CW = carcass weight; LMC = lean meat content; LW = live weight; MT = muscle thickness

Lighter carcasses were observed in classes S and E, while heavier carcasses were observed in the other classes. The same pattern was reported by Font-i-Furnols et al. (2016). Live weight followed the same pattern as carcass weight. In this regard the authors reported a higher percentage of belly (Valis et al. 2005) and observed higher moisture and fat content in animals with higher live weight (Ba et al. 2019) and, on the other hand, they found out higher protein contents in lighter pigs. Other authors (Candek-Potokar et al. 1998) similarly reported higher intramuscular fat content in pigs with higher weights at slaughter, which were related with the higher age of animals. Moreover, in the case of higher weights due to higher age more pigment in meat was observed (Durkin et al. 2012). Although there is a possibility to improve the quality of the carcass by increasing its weight for a longer feeding period, the economic reasons might not be in favour of this approach since profitability is highly dependent on carcass price and average daily gain (Sprysl et al. 2010) and actual payments do not cover increased feeding costs related to higher quality of carcass and meat.

Correlations between the studied carcass characteristics are summarized in Table 9. Since some differences were observed between the methods, correlations were calculated in respect to the method of classification. All the correlations were statistically significant (P < 0.001). Different correlations between carcass characteristics were reported by Font-i-Furnols et al. (2016) for different national datasets from European countries. They reported no or low negative correlations between BT and MT measured by the TP meth-

https://doi.org/10.17221/231/2020-CJAS

Table 9. Pearson correlation coefficients according to classification method

	FOM			UFOM		
	BT	MT	LMC	BT	MT	LMC
CW	0.36	0.35	–0.14	0.36	0.20	–0.29
BT		–0.11	–0.88		0.02	–0.93
MT			0.56			0.20

BT = backfat thickness; CW = carcass weight; FOM = Fat-O-Meater; LMC = lean meat content; MT = muscle thickness; UFOM = Ultra Fat-O-Meater 300

od and positive correlations between BT and CW (0.30–0.55), and MT and CW (0.33–0.58). Similar correlations were reported by Kvapilik et al. (2009) in the pig population in the Czech Republic. In our study a slightly lower correlation was observed between MT and LMC measured with UFOM instrument.

Changes in the studied carcass characteristics are presented in Figures 1, 2 and 3. These changes were only slight in the studied period. Due to the stronger negative dependence of LMC on BT than on MT, the trends of BT (Figure 2) and LMC (Figure 3) were opposite. The trend of MT (Figure 3) was increasing independently of the BT trend, which is in agreement with low calculated correlations between BT and MT. When average values from the studied period were compared with data used in the authorization trial (2009), the changes in characteristics were considerable (Table 10). The trend of decreasing backfat thickness while improving the muscle thickness of the *longissimus dorsi* muscle may be observed especially in pigs coming from Danish breeding program, thus in the group of major slaughterhouses using the FOM instrument and slaughtering a higher portion of these pigs. On the other hand, UFOM is used in the slaughterhouse where a higher portion of Slovak pigs was supplied and the change of carcass characteristics was not so high in this group.

Table 10. Change of the carcass characteristics (2009–2019)

Method	Year	BT (mm)		MT (mm)		LMC (%)	
		average	SD	average	SD	average	SD
FOM	2009	22.25	6.16	57.71	6.59	56.10	4.10
	2015–2019	13.74	3.80	62.27	8.56	62.09	2.84
UFOM	2009	15.37	3.34	57.54	11.36	57.23	2.66
	2015–2019	15.07	4.59	60.87	10.76	57.96	3.64

BT = backfat thickness; FOM = Fat-O-Meater; LMC = lean meat content; MT = muscle thickness; UFOM = Ultra Fat-O-Meater 300

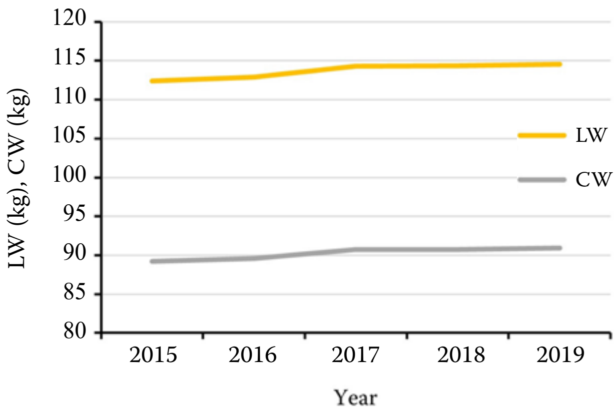

Figure 1. Changes of live (LW) and carcass weight (CW) (2015–2019)

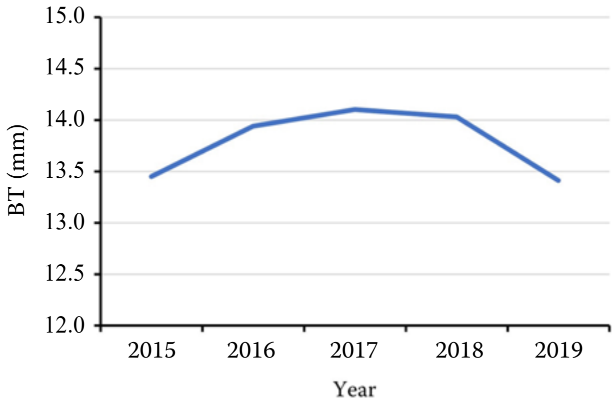

Figure 2. Changes of backfat thickness (BT) (2015–2019)

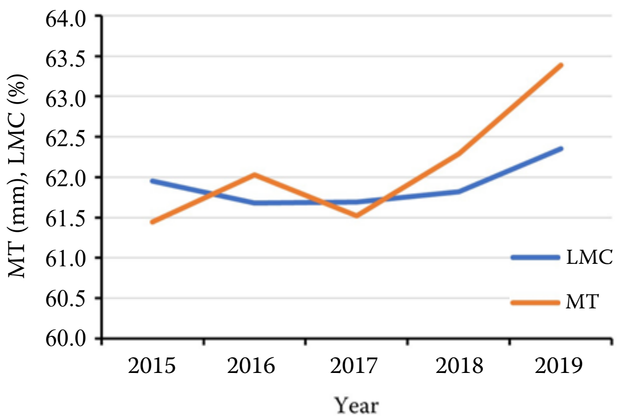

Figure 3. Changes of muscle thickness (MT) and lean meat content (LMC) (2015–2019)

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CONCLUSION

Considerable changes were observed regarding the origin of slaughtered animals in the studied period. There was an increasing portion of animals from foreign breeding programs and animals from abroad while the number of slaughtered animals with Slovak origin was decreasing. Slight changes were observed in the last five years considering the distribution of pig carcasses within the SEUROP classification classes. However, when comparing the year 2019 and the year 2009 (adoption of equations), a considerable change in the distribution of carcasses was observed. Also, changes can be observed when single characteristics are compared between the two years. These changes in characteristics resulting in different distribution of carcasses according to SEUROP classification suggest that the updating of actual equations for pig carcass classification methods should be undertaken in the near future. Differences between methods were only slight giving only limited space for new regression equations to improve the classification objectiveness. Results also showed that most of the carcasses are classified within the S and E classes. This concentration of carcasses in two classes can be solved by introducing subclasses. Moreover, this situation suggests the possibility of using sire lines improving the quality of meat and including new traits (meat quality) in pig carcass classification, since there is an increasing number of consumers who are interested and willing to pay more for high-quality pork.

Conflict of interest

The authors declare no conflict of interest.

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