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THE EFFECT OF THE SLAUGHTER WEIGHT ON CARCASS COMPOSITION, BODY MEASUREMENTS AND VEAL QUALITY OF HOLSTEIN CALVES

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Abstract

The aim of this study was to investigate the growth, fattening characteristics and veal quality of MLT from Holstein calves (total number of 40 heads) produced from 4 slaughter weight groups (130, 150, 180 and 210 kg). Calves were fed in the same conditions. Average daily gains ranged from 660 g in slaughter weight 130 kg to 840 g in weight 210 kg ($P < 0.001$). The most important changes of linear body measurements were revealed in hip height and withers height ($P < 0.001$). Slaughter weight had strong impact on average daily gain and most of body measurements ($P < 0.01$). Slaughter weight influenced proportion of kidney, rumen and intestinal fat, while highest proportion was found in the group of 180 kg ($P < 0.001$). Calves of slaughter weight 180 kg had lowest proportion of bones ($P < 0.001$) and highest proportion of meat ($P < 0.001$) from right – half carcass. Highest proportion of separable fat had calves of 210 kg as well as 150 kg. In terms of nutritional quality of veal, we found significant and high individual differences in intramuscular fat content ($P < 0.01$) as well as between monitored groups. The lightness of the meat was highest in the group of 180 kg ($P < 0.05$). Protein content of the loin muscle had negative impact on intramuscular and moisture content ($P < 0.001$). Parameter pH strongly positively influenced drip loss value and negatively electrical conductivity.

Keywords: body measurements, carcass composition, correlations, Holstein breed, lightness, pH value, separable fat, veal

INTRODUCTION

Each consumer chooses a variety of livestock meats depending on to their personal needs, taste and possibilities. Cattle allow for a selection of many slaughter animals (Mojto *et al.*, 2009). The beef sector (including veal) in Europe is very variable and allows different slaughter categories of cattle for processing and direct consumption (calves, baby beef, bulls, heifers, steers and cows). Large numbers of production systems are based on different systems of fattening as well as breeding and utility types (Domaradzki *et al.*, 2017). Each category is characterized by specific needs in the production phase of meat production and there are also differences in the quality of carcasses and meat (Mojto *et al.*, 2009). In general, information about the production, export/import and veal consumption is noted together with beef. In global meat production and consumption, veal is relatively less significant commodity compared to beef, pork, lamb and poultry (Ngapo and Gariépy, 2006).

The definitions of veal are various according to its origin. Generally in many countries, veal is defined with age limit of 7 months and a weight of 250 kg (EC, 2003). With regard to animal welfare standards and the perception of the meat industry by consumers, veal sector had changed over the past 50 years, particularly in production systems (accepting heavier calves) and in housing from individual crates to group housing (Ngapo and Gariépy, 2006). Nowadays, when dairy breeds predominate in the composition of the bovine population, with milk as the main commodity, males of these breeds will be the main source of beef. This is confirmed by the findings of Lengyel *et al.* (2003), who reported that the Holstein bulls provide a significant proportion of the beef worldwide consumption. Their meat has good quality characteristics when fattening to the lower slaughter weights and therefore the lack of veal could be replaced by the calf meat of dairy breeds. This also results from the fact that the utilization of specialized beef cattle or crossbreeds with a high growth rate for veal production would be economically disadvantageous. Due to the relatively high prices of beef compared to other meats (pork, poultry) is quality of the meat particularly important (Bureš and Bartoň, 2012).

Achieving the highest possible quality is necessary to satisfy consumers, allure on repurchase and to maintaining and increasing global market share (Coleman *et al.*, 2016). For the modern consumer, the most important quality characteristics of meat are flavour and nutritional value (Webb and O'Neill, 2008); the colour of veal is not of great importance within the EU (Florek *et al.*, 2009). Beef is characterized by a relatively high score of odour and flavour intensity (Bureš and Bartoň, 2012). The meat quality criteria are influenced by a number of pre-slaughter factors, such as: management, feeding, growth rate, length of fattening, final weight and carcass processing method after slaughter as well (Williams, 2008). One of important factors affecting the meat quality is age of animals (Li *et al.*, 2018). Age and slaughter weight are usually evaluated as a common trait. Measurable and observable carcass characteristics are often used to assign the value of beef (Coleman *et al.*, 2016).

MATERIALS AND METHODS

For this experiment a total of 40 young bulls (n = 40) of Holstein were used. Calves for this experiment were born within one week. All animals were reared at the local farm in standard feeding conditions. In the first stage of the experiment calves were kept in the individual crates. They received basal diet with the milk replacer and the starter feed mixture. After weaning (about 60 days) they were housed together on straw litter divided into 4 groups according to the required final weight, 10 calves each. All animals were fed with the total mixed ration composed of maize silage, alfalfa silage and feed mixture two times per day. Drinking water was available from birth *ad libitum*. Calves were slaughtered after reaching the average required live weight of 130 kg (group I), 150 kg (group II), 180 kg (group III) and 210 kg (group IV) as well. At the end of the experiment, calves were weighed and measured. Selected body measured were evaluated: wither height, hip height, back length (between withers and hip join), heart girth, hip width and rump length. The calves were dressed in experimental abattoir of Department of Animal husbandry SUA in Nitra, according to standard methods, using a captive bolt stunner, sticking and bleeding.

The carcasses were immediately chilled at 4 °C for 24 h after slaughter and subsequent split into hindquarter and forequarter of right-half carcass and left-half carcass. Immediately, detailed dissection of the right side of each carcass was carried out. For the proximate composition (moisture, protein, intramuscular fat), physico technological and qualitative parameters, slices of *M. longissimus thoracis* (MLT) were taken 24 hours *post mortem*. We evaluated fattening and carcass characteristics, body measurements, veal quality parameters and correlations between selected characteristics using the Pearson´s coefficient of correlation. For statistical evaluations were used the Statistical Analysis System (SAS) version 9.3 (TS1M2) Enterprise Guide 5.1. (SAS INSTITUTE Inc., 2011).

RESULTS AND DISCUSSION

Tab. I represents selected fattening and carcass characteristics of Holstein calves slaughtered in different weights. The highest average daily gain (from born to the end of fattening) was found in calves of the group slaughtered in average weight of 210 kg. Contrariwise, calves of lowest weight category (130 kg) had lowest ADG ($P < 0.001$). Higher values of ADG (1078 g) found Cozzi *et al.* (2002) in Holstein calves slaughtered in weight of 229.2 kg. No significant differences were found in the dressing percentage, whereas the highest dressing percentage (51.02%) had calves of heaviest group ($P > 0.05$). Yim *et al.* (2015a) noted dressing percentage 59.1% in Holstein bulls slaughtered in higher weight (270 kg). Dressing percentage of 48.3% found Chládek and Falta (2006) in Holstein bulls fattening up to 300 kg. Mostly significant changes from all monitored body measurements were estimated in height measurements among the weight groups. The greatest development we found in withers height (HTW) and hip height among the groups up to the weight of 180 kg. Values of heart girth mostly increased between groups of 150 kg and 180 kg. Conversely, back length associated with

I: *Fattening and carcass characteristics of Holstein veal in different slaughter weights*

Variables		Final weight				P
		130 kg (n = 10)	150 kg (n = 10)	180 kg (n = 10)	210 kg (n = 10)	
Birth weight (kg)		37.78[b] ±0.99	38.22[b] ±0.58	39.40[a] ±1.43	39.80[a] ±0.90	0.0001
Final weight (kg)		130.40[d] ±8.38	150.30[c] ±3.49	179.00[b] ±10.17	210.00[a] ±15.34	< 0.000111
Average daily gain (g)		660[c] ±100	740[b] ±20	710[bc] ±70	840[a] ±60	< 0.0001
Feeding days		141.60[c] ±16.38	151.80[b] ±4.08	198.20[a] ±5.24	203.40[a] ±4.84	< 0.0001
Dressing percentage (%)		50.73 ±1.77	49.79 ±1.75	49.78 ±0.55	51.02 ±1.29	0.1322
BM (cm)	HTW	96.20[c] ±3.74	103.80[b] ±2.94	112.00[a] ±1.87	113.80[a] ±2.86	< 0.0001
	Hip height	100.50[c] ±3.33	106.60[b] ±2.80	114.40[a] ±0.73	116.00[a] ±3.40	< 0.0001
	HGT	127.80[b] ±5.59	130.80[b] ±2.04	140.00[a] ±1.86	143.40[a] ±4.88	< 0.0001
	BKLT	58.00[c] ±2.49	61.40[b] ±1.58	62.20[b] ±5.50	67.00[a] ±2.75	< 0.0001
	RLT	35.60 ±13.41	36.60 ±1.43	36.50 ±0.53	36.80 ±0.79	0.7623
	Hip width	24.40[b] ±1.71	24.60[b] ±0.52	29.00[a] ±0.93	29.40[a] ±1.84	< 0.0001

Values are mean ± standard deviation, HTW – withers height, HGT – heart girth, BKLT – back length, RLT – rump length
[a-c] means with different superscripts within a row are significantly different (P < 0.05)

II: *Mutual correlations between fattening characteristics and body measurements (n = 40)*

	Final weight	ADG	HTW	HHT	BKLT	HGT	HPW	RLT	Slaughter weight
Birth weight	0.623**	0.396*	0.539**	0.601**	0.363*	0.719**	0.553**	0.127	0.603**
Final weight		0.753**	0.861**	0.844**	0.729**	0.904**	0.803**	-0.003	0.990**
ADG			0.499**	0.466**	0.541**	0.651**	0.450**	0.182	0.752**
HHT				0.980**	0.600**	0.799**	0.773**	-0.070	0.861**
HTW					0.568**	0.773**	0.776**	-0.106	0.843**
BKLT						0.620**	0.538**	-0.004	0.710**
HGT							0.785**	0.278	0.900**
HPW								-0.191	0.803**
RLT									0.035

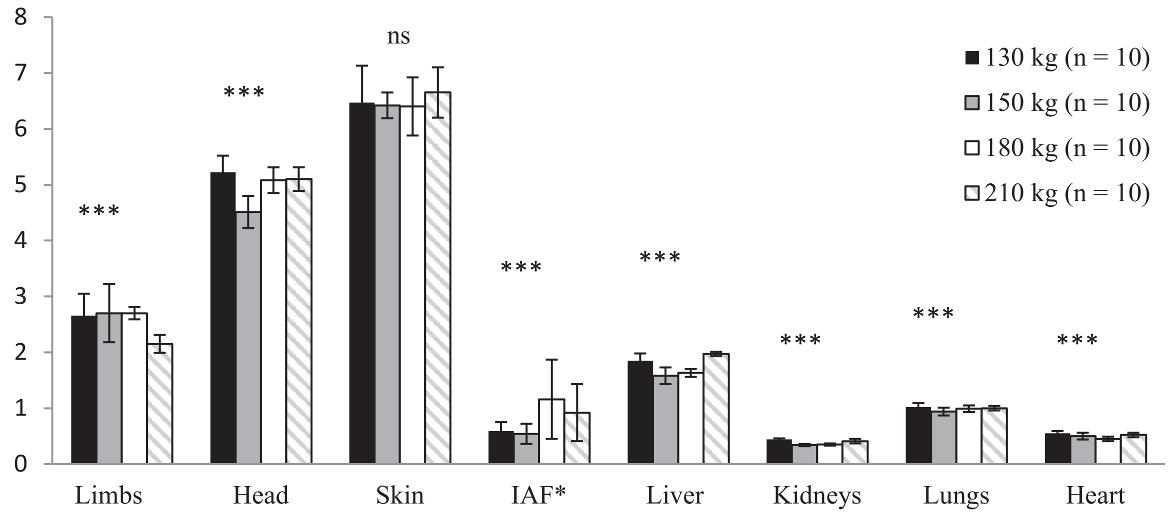
ADG – average daily gain, HTW – withers height, HHT – hip height, BKLT – back length, HGT – heart girth, HPW – hip width, RLT – rump length

most valuable meat cuts mostly changed between calves of 180 kg and 210 kg. Non significant differences were found in measurement rump length. According to Domaradzki *et al.* (2017) growth models and veal carcass quality are influenced by different feeding and management. Linear body measurements are used for evaluation of growth rate, weight, feed utilization and carcass quality of livestock. These measurements describe animal better than conventional methods of weighing and grading, as noted in Essien and Adesope (2003). Kusuma *et al.* (2017) found in Ongole Crossbred Cattle of weight 120.5 kg withers height 101.40 cm and heart girth 110.62 cm. Our results in the group of 180 kg are slightly higher than those of Wilson *et al.* (1997) for withers height (112 cm vs. 104.9 cm), heart girth (140 cm vs. 132.9 cm) and lower for hip width (29 cm vs. 37 cm).

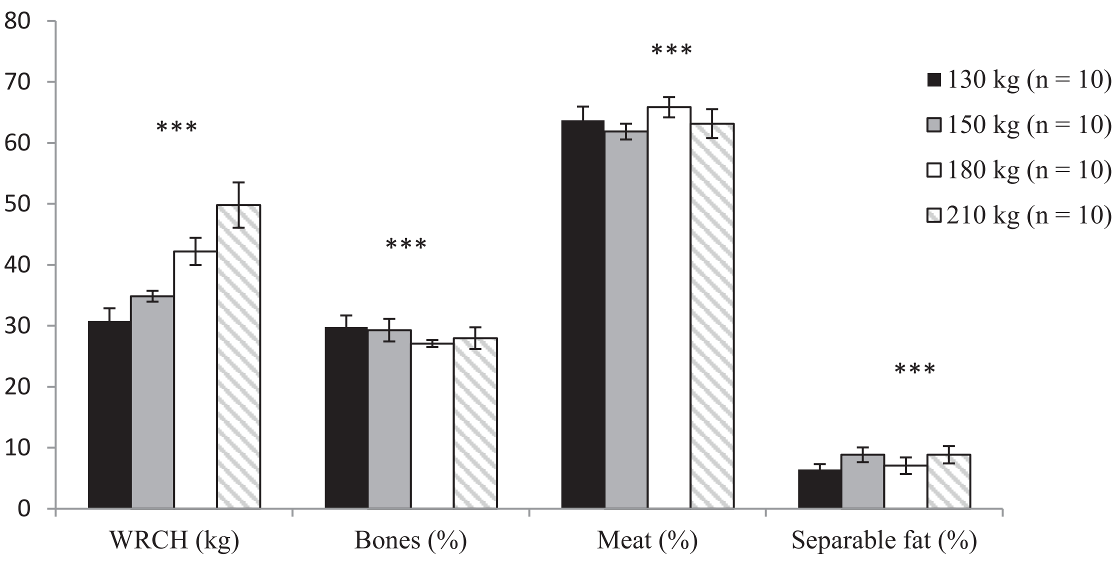
Correlation coefficients between fattening characteristics and body measurements are described in Tab. II. Very low correlations were found between rump length and other monitored linear measurements. We estimated strongly significant relationship between body measurements and birth live weight, final live weight and average daily gain as well. The correlation coefficient (0.861**) between final weight and withers height was higher than those of Ozakaya and Bozkurt (2009) (0.66). The high correlation between final weight and heart girth (r = 0.90**) were higher than Lukuyu *et al.* (2016). Ozakaya and Bozkurt (2009) found correlation r = 0.78 between body weight and heart girth. Strong relationship between mentioned characteristics more reflects the animal´s body condition than body length and height at withers.

With increasing slaughter weight of the calves also weight of the abdominal and thoracic organs (Fig. 1) increased (P < 0.001). There was a increase in the proportion of fore-limbs and hind-limbs up to slaughter weight 180 kg, whereas heaviest calves had lowest proportion of limbs (P < 0.001). The most significant differences were found in the proportion of head (from slaughter weight) in the group of lightest calves (P < 0.001). Slightly different results found Ahmad *et al.* (2013) in native breed Lohani (LW 204 kg) for head (4.2%), skin (9%) and limbs (1.8%). In line with our findings, Zhang *et al.* (2017) noted in Jersey proportion of heart 0.61%, liver 1.76% and kidneys 0.45%. Proportions of intra-abdominal fat (kidney, intestinal and rumen) were highest in the group with slaughter weight 180 kg (P < 0.001). Dairy breeds tend to deposit more intra-abdominal fat than, whereas beef transform the nutrients mainly into proteins. The variability and development of fat tissue is influenced by several factors i.e. breeds physiological ages and growth potential (Albertí *et al.*, 2008). Florek *et al.* (2009) obtained proportion of kidney fat according to slaughter weight – 0.84% in 74.63 kg, 0.80% in 70.38 kg and 0.66% in 66.94 kg as well.

Proportions of individual tissues from the right-half carcass in monitored weight groups of calves are shown in Fig. 2. We found decreasing proportion of bones from carcass (marrow, technical, pelvis, scapula) with increasing slaughter weight (P < 0.001), which confirms changes in ratio of individual tissues during growth. We found significant differences between the 130 kg and 180 kg slaughter weight groups when calculating



1: *Proportions of parts of carcass not included to the weight of meat (%)*
*IAF = intra - abdominal fat (rumen, intestinal, kidney); *** p < 0.001



2: *Proportion of individual tissues from the right-half carcass*
WRHC – weight of right-half carcass, % values were calculated from WRHC, *** p < 0.001

the amount of the meat to the proportion of the half carcass weight ($P < 0.05$). The lowest proportion of separable fat was obtained in the weight group 130 kg (6.47%) and 180 kg (7.06%). At the same time, the highest variability in the proportion of separable fat of both the fore quarter and hind quarter was found between weight groups. Similar results in the proportion of meat from right-half carcass in group of 180 kg (66.74%) were noted in Santos *et al.* (2013).

In Tab. III are shown correlation coefficients between body measurements and carcass characteristics. We found highly significant relationships between body measurements and weight of individual meat parts. Body measurement rump length did not correlated with mentioned characteristics.

In Tab. IV we describe the contents of moisture, protein and intramuscular fat of the MLT from Holstein bull calves. The intramuscular fat content increased and moisture content decreased as the slaughtering weight increased up to the weight of 180 kg. The moisture content of MLT sample (75.27%) from the group of 180 kg was significantly higher than those of 150 kg (74.56%; $P < 0.05$). The MLT samples from group of calves with slaughter weight of 210 kg had significantly higher protein content (23.00%; $P < 0.05$) and significantly lower IMF content (1.57%; $P < 0.05$) than those of 180 kg. The fat content (2.15%) and energy value (454.49 kJ) of the loin muscle from group of 180 kg was slightly higher than other 4 slaughtering weight groups. Although we mentioned lower average content of IMF between slaughter groups 130 kg and 150 kg, there were high individual differences. According to Huff and Lonergan (2010) the moisture content of meat is variable due to species, breed, age of animal, nutrition and its morphological – anatomical origin. Our results of the moisture content are similar to those of the loin muscle shown by Yim *et al.* (2015a). Cho *et al.* (2014) reported that the *M. longissimus dorsi* from 6 month old Holstein calves contains 76.27% moisture, 22.30% protein and 1.42% intramuscular fat.

Physicochemical properties associated with the quality of meat (pH, EC, drip loss and colour parameters) of the loin muscle from Holstein calves measured 24 hours *post mortem* are described in Tab. V. We did not found significant differences in drip loss and pH value measured 24 hours *post mortem* among slaughtering weight groups ($P > 0.05$). Values of pH ranged from 5.94 (group with slaughter weight 150 kg) to 6.03 (group of 130 kg). Among slaughter weight groups of 180 kg and 210 kg drip loss values ranged between 1.02 and 1.29. Skřivanová *et al.* (2007) found values of drip loss 1.38% in Holstein bulls fattened with total mixed ration to the slaughter weight of 163.5 kg. As written by Ripoll *et al.* (2013) drip loss is the result of *post mortal* lateral retraction of myofibrils, which cause the water segregation to the extracellular space of the muscles. Yim *et al.* (2015b) noted slightly lower pH of the loin muscle 5.77. The effect of pH value is often associated with the meat colour as described Ngapo and Gariépy (2006) and generally is measured subsequently. The rate of pH decrease influences the meat colour greater or lesser depending on the pigment content of the individual muscles. Meat colour is one of important determinant of visual appearance which influence purchase probability. The L^* value increased among monitored groups up to slaughter weight 180 kg; the lightness of the meat (characterized with higher L^* value) was highest in the group with slaughter weight 180 kg (46.01; $P < 0.05$). The meat from the heaviest calves was also darkest when compare with other slaughter weight groups ($P < 0.05$). The veal from Holstein slaughtered in 130 kg showed very light meat characterized with lowest a^* value. Our results are similar to those of Yim *et al.* (2015a) for L^* value of the MLT.

The correlation coefficient between physical technological parameters and chemical composition are presented in Tab. VI. Above analysis resulted in significant negative correlation between intramuscular fat content and protein content. Significant relationship was found between pH_{24} value and drip loss (0.337^{*}). As noted in Page *et al.* (2001), higher pH value of muscle resulted to the lower values of free water due to better ability of proteins to bind with water. Hence, muscles with higher pH value will be darker due to reduced free water content to reflect the light. Negative significant correlation was found between pH and electrical conductivity (-0.403^{**}). Significant positive correlation was estimated between intramuscular fat content and colour yellowness (0.485^{**}) as well as between colour lightness and yellowness (0.596^{**}). Little negative effect was determined between colour lightness and redness. Higher correlation coefficients between meat pH and meat lightness (-0.24) found Weglarz (2010). Page *et al.* (2001) noted correlations between pH and all colour parameters: L* -0.40, a* -0.58, b* -0.56. According to authors is pH of the muscles most associated with the redness and yellowness, while pH affects the meat colour by altering hue more than lightness/darkness.

III: *Mutual correlations between body measurements and carcass characteristics (n = 40)*

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	IAF
HTW (X1)	0.980**	0.600**	0.799**	0.773**	-0.070	0.851**	0.855**	0.903**	0.871**	0.743**	0.890**	0.719**	0.731**	0.853**	0.631**	0.721**
HHT		0.568**	0.773**	0.776**	-0.106	0.831**	0.850**	0.889**	0.850**	0.727**	0.875**	0.703**	0.751**	0.852**	0.576**	0.698**
BKLT (X2)			0.620**	0.538**	-0.004	0.727**	0.722**	0.668**	0.674**	0.760**	0.659**	0.586**	0.764**	0.657**	0.668**	0.664**
HGT (X3)				0.785**	0.278	0.891**	0.885**	0.884**	0.886**	0.814**	0.890**	0.775**	0.789**	0.868**	0.735**	0.826**
HPW (X4)					-0.191	0.812**	0.804**	0.772**	0.838**	0.734**	0.825**	0.633**	0.746**	0.794**	0.601**	0.861**
RLT (X5)						0.007	0.049	0.065	0.102	-0.064	0.054	0.103	-0.076	0.124	-0.071	-0.001
WHQ (X6)							0.962**	0.957**	0.926**	0.940**	0.979**	0.855**	0.912**	0.919**	0.833**	0.753**
WFQ (X7)								0.935**	0.899**	0.933**	0.944**	0.783**	0.932**	0.972**	0.776**	0.791**
Top round (X8)									0.947**	0.853**	0.982**	0.836**	0.847**	0.924**	0.707**	0.715**
Sirloin (X9)										0.813**	0.964**	0.820**	0.792**	0.909**	0.633**	0.763**
Bones – HQ (X10)											0.868**	0.773**	0.962**	0.843**	0.834**	0.720**
Meat – HQ (X11)												0.844**	0.850**	0.939**	0.729**	0.732**
Shoulder (X12)													0.784**	0.704**	0.759**	0.585**
Bones – FQ (X13)														0.839**	0.781**	0.699**
Meat – FQ (X14)															0.650**	0.783**
SPF (X15)																0.645**

HTW – withers height, HHT – hip height, BKLT – back length, HGT – heart girth, HPW – hip width, RLT – rump length, WHQ – weight of hindquarter, WFQ – weight of forequarter, HQ – hindquarter, FQ – forequarter, SPF – separable fat, IAF – intra abdominal fat

IV: *Nutritional quality of veal from Holstein calves in different slaughter weights*

Variables	Final weight				P
	130 kg (n = 10)	150 kg (n = 10)	180 kg (n = 10)	210 kg (n = 10)	
Protein	22.45 ±0.72	22.79 ±0.95	22.29[b] ±0.86	23.00[a] ±0.56	0.1823
Moisture	75.02 ±0.58	74.56[a] ±0.55	75.27[b] ±0.95	74.65 ±0.98	0.1618
IMF	1.31[a] ±0.68	1.55[a] ±0.59	2.15[b] ±0.81	1.57[a] ±0.65	0.0047
EV	425.31[a] ±29.92	440.02 ±9.32	454.49[b] ±20.48	436.69 ±13.77	0.0298

Values are mean ± standard deviation, IMF – intramuscular fat, EV – energy value
[a,b] means with different superscripts within a row are significantly different ($P < 0.05$)

V: *Physical technological parameters of veal from Holstein calves in different slaughter weights*

Variables		Final weight				P
		130 kg (n = 10)	150 kg (n = 10)	180 kg (n = 10)	210 kg (n = 10)	
pH_{24}		6.03 ±0.19	5.94 ±0.04	5.99 ±0.05	6.00 ±0.10	0.3575
EC24		2.46[ab] ±0.50	2.64[ab] ±0.54	2.20[b] ±0.19	3.02[a] ±1.07	0.0556
Drip loss		1.04 ±0.51	1.07 ±0.18	1.02 ±0.65	1.29 ±0.31	0.4830
Meat colour 24 h	Lightness (L*)	44.87[a] ±2.85	45.42[a] ±4.04	46.01[a] ±3.43	42.09[ab] ±1.45	0.0124
	Redness (a*)	4.03[a] ±0.84	6.82[b] ±1.20	5.35 ±1.88	5.41 ±5.02	0.2285
	Yellowness (b*)	9.49 ±0.71	9.82 ± 1.06	10.18 ±0.63	9.76 ±0.76	0.4651

Values are mean ± standard deviation, EC – electrical conductivity
[a,b] means with different superscripts within a row are significantly different ($P < 0.05$)

VI: *Mutual correlations between physical technological parameters and chemical composition of veal (n = 40)*

	IMF	Moisture	pH24	drip loss	EC24	L*	a*	b*
Protein	-0.466***	-0.692***	0.272	0.115	0.047	-0.130	0.065	0.148
IMF		0.389*	0.266	0.203	-0.283	0.289	0.036	0.485**
Moisture			-0.161	0.239	-0.023	0.133	-0.244	0.164
pH24				0.337*	-0.403**	-0.081	-0.016	0.321*
drip loss					0.291	-0.207	0.054	0.372
EC24						-0.148	-0.166	-0.092
L*							-0.050	0.596**
a*								0.175

IMF – intramuscular fat, EC – electrical conductivity, L* – lightness index, a* – redness index, b* – yellowness index

CONCLUSION

Monitoring of growth, carcass characteristics, veal quality and mutual correlation between monitored characteristics of Holstein calves differentiated according slaughter weight has become an object of concern. Positive and significant interrelationships between high measurements as well as back length and weight of valuable meat cuts were confirmed. From the point of view of the favourable carcass composition and meat colour, the optimal carcass weight for fattening of Holstein calves seems up to 180 kg. Although we found a high dressing percentage in slaughter weight 130 kg, carcasses had the highest proportion of bones (especially the high percentage of marrow bones) and a low proportion of the loin muscle. Even though calves of 210 kg in this study had highest dressing percentage, they had also highest proportion of technical bones and separable fat and moreover lower meat lightness among other slaughter weight groups.

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