Table 5 Pig meat quality in relation to the crude protein level in forage mixtures

Indicators	Stat. size	Crude protein level	
		A (higher)	A (higher)
pH_1	$\bar{x}$	6,23^{NS}	6,47
	s	0,27	0,21
pH_2	$\bar{x}$	5,61*	5,75
	s	0,20	0,19
Water holding capacity, cm^2	$\bar{x}$	4,65**	3,06
	s	1,64	1,33
Colour (L* value)	$\bar{x}$	51,15**	48,27
	s	2,41	4,35
Colour (a* value)	$\bar{x}$	18,43*	19,28
	s	1,22	0,95
Colour (b* value)	$\bar{x}$	6,04^{NS}	5,47
	s	0,99	1,23
Consistency, cm^2	$\bar{x}$	2,58^{NS}	2,15
	s	0,76	0,42
Crude proteins, %	$\bar{x}$	21,47*	20,93
	s	0,72	0,84
Crude fat, %	$\bar{x}$	6,89**	12,34
	s	2,81	3,48
Ash, %	$\bar{x}$	1,02^{NS}	1,02
	s	0,04	0,05
Water, %	$\bar{x}$	70,62**	65,70
	s	1,21	2,75

*p<0,05 **p<0,01 NS-nije značajno / non significant

groups and better than the one earlier determined for pig breeds of meat type and their crossbreds *(Senčić et al., 2002.; Senčić et al., 2003; and Senčić et al., 2005).*

Muscle tissue consistency, expressed as the area of filter paper wetness below compressed meat, was also standard and no significant differences were detected between the analyzed groups.

Crude protein level in forage mixtures also significantly influenced the chemical composition of meat. Meat of pigs that were fed forage mixtures with higher crude protein level (Group A) had a significantly (p<0.05) higher content of crude proteins, a very significantly (p<0.01) higher water content, and a very significantly (p<0.01) lower content of crude fat in relation to meat of pigs that were fed forage mixtures with lower crude protein level (Group B). No significant differences (p>0.05) were detected between the analyzed groups in terms of ash content.

Conclusion

Increased crude protein level in forage mixtures had a very significant (p<0.01) influence on reduction of fat tissue share (34.55% : 39.09%) and on increase in muscle tissue share (47.10% : 46.11%) in pig carcasses, although not to a statistically significant extent (p>0.05). Pig carcasses from Group A (higher crude protein level) in relation to those from Group B (lower crude protein level) had significantly (p<0.01) higher share meat of ham (15.62% : 14.62%). Meat (MLD) of pigs from both groups was of very good quality, considering the analyzed indicators (pH_1, pH_2, water holding capacity, and colour). The meat from the Group A pigs, in relation to the meat from the Group B pigs, had a significantly (p<0.05) higher crude protein content (21.47% : 20.93%), a very significantly (p<0.01) higher water content (70.62% : 65.70%), and the lower crude fat content (6.89% : 12.34%), while in terms of ash (1.02% : 1.02%) no significant differences (p>0.05) were detected between the analyzed groups of pigs.

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Variations in carcass and meat quality traits of heavy pigs

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Scientific paper

Summary

This research was performed on 45 randomly chosen carcasses originating from double-crossed gilts (Large White and Swedish Landrace). The gilts were housed in the same conditions and fed the same diet during the fattening period until the slaughter, when carcass and meat quality traits were measured. The samples for chemical analysis of the meat were also taken. The mean pH_{45} and pH_{24} value measured in LD muscle of pig carcasses were 6.23 and 5.6, respectively, implying normal meat quality. The mean value of electrical conductivity measured 45 minutes post mortem, EC_{45} was 4.38 mS/cm, indicating no deviation from normal quality of meat, while mean EC_{24} value was 9.74 mS/cm which could be considered as relatively high. At the same time, mean CIE-L value (52.43) indicated to some extent paler than normal meat of the investigated pigs. Average drip loss (8.29 %) could also be considered as higher than desirable. When the samples were divided into normal (n=37; 82.22%) and PSE (n=8; 17.78%) group on the basis of pH_{45} value, significant differences could be observed in LD muscle area indicating increased lean production in PSE group. Regarding the meat quality traits, groups significantly differed in pH_{45}, EC_{45} and cooking loss, while there were no differences in chemical composition. Both groups had undesirably high values of EC_{24}, CIE-L* and drip loss, with no significant differences between the formed groups. The F-test performed to analyze the influence of warm carcass weight on carcass traits revealed positive effect on carcass length, ham circumference and back fat area. In the present study, only pH_{24}, EC_{24} and CIE-a* values were found to be influenced by warm carcass weight; the chemical composition of the meat samples was unaffected by warm carcass weight. It was concluded that the common positive perception about the meat quality of heavy pigs between the pig producers should be taken with caution.*

***Key words:** heavy pigs, carcass traits, meat quality traits*

Introduction

Breeding of heavy weight pigs presents an important source of raw meat in the production of dry- cured products. It is widely known that increased muscularity of modern genotypes of fattening pigs caused by intensive selection have a negative effect on meat color and water holding capacity. On the other side, heavy pigs are characterized by increased fat content in the carcasses and poor feed conversion ratio, especially in last days of fattening. However, by increasing body weight, higher carcass yield can be achieved, while cooling and meat processing costs can be reduced (Ellis and Bertol, 2001). Some investigations showed that increasing age at slaughter may result in an improvement of certain pork quality traits (Candek-Potokar et al., 1998). Meat quality of older animals rather differs from that of younger animals. Numerous authors approved that increasing age and weight of pigs at slaughter may result in a more intense color of meat (Berry et al., 1970; Martin et. al., 1980) and higher intramuscular fat content (Lawrie et al., 1963; Allen et al., 1967; Shuler et al., 1970; Malmfors et al., 1978; Candek-Potokar et al., 1998). Results of Piao et al. (2004) showed that meat that comes from heavy- weight pigs had higher juiciness and tenderness, which represents desirable characteristics in production of meat products, which could be a result of higher intramuscular fat content (Hugo et al. 1999). In the aim of achieving desirable quality, a prediction of meat quality together with economic efficiency should be performed well and on time, because the market of meat and meat products becomes more competitive. Pork processors and the pork producers could suffer economic losses if the appropriate meat quality is not achieved (Chan et al. 2002). The researches about the influence of slaughter weight on technologi-

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Table 1 Descriptive statistics of measured carcass characteristics, meat quality traits and chemical composition of heavy pigs

Trait	Mean	Min	Max	Standard deviation
Carcass trait				
Warm carcass weight (kg)	152,80	125,00	187,00	14,88
Carcass length – „a" (cm)	103,80	94,00	113,00	4,51
Carcass length – „b" (cm)	121,40	111,00	134,00	6,44
Ham length (cm)	39,96	37,00	43,00	1,48
Ham circumference (cm)	85,44	79,00	90,00	2,76
LD muscle area (cm²)	64,07	44,53	91,40	9,67
Back fat area (cm²)	36,55	18,45	57,15	9,33
Meat quality traits				
*pH_{45}	6,23	5,46	6,74	0,32
**pH_{24}	5,69	5,42	6,36	0,24
***EC_{45}, (mS/cm)	4,38	1,40	12,70	2,35
****EC_{24}, (mS/cm)	9,74	3,70	12,90	2,30
CIE - L*	52,43	42,24	64,22	5,12
CIE - a*	9,69	4,22	14,80	2,65
CIE - b*	4,84	1,44	10,09	2,13
Drip loss (%)	8,29	2,40	14,49	3,00
Cooking loss (%)	31,88	26,24	36,27	1,92
*****WBSF (N)	60,43	47,95	73,64	6,92
Chemical composition				
Fat (%)	2,59	1,35	4,41	0,62
Water (%)	73,07	71,38	74,92	0,71
Protein (%)	24,33	22,98	25,50	0,64
Collagen (%)	0,96	0,53	1,38	0,18

*pH_{45}-pH measured 45 minutes *post mortem*;**pH_{24}-pH measured 24 h *post mortem*;***EC_{45}-electic conductivity measured 45 minutes *post mortem*;****EC_{24}-electric conductivity measured 24 h *post mortem*; ******WBSF-Warner Bratzler Shear Force

cal meat quality characteristics in Croatia are scarce, so the aim of this study was to give some insight in carcass and meat quality traits of heavy pigs as well as in the chemical composition of their meat.

Material and methods

The research was performed on 45 randomly chosen carcasses originating from Large White and Swedish Landrace crossed gilts. The gilts were housed in the same conditions and fed the same diet during the fattening period; at approximately 12 months of age the gilts were slaughtered in one slaughterhouse in east Croatia. The researched carcass measurements included: warm carcass weight, carcass length, ham length, ham circumference, back fat and *longisimuss dorsi* (LD) muscle area. The length of the carcass was measured from *os pubis* to the 1st rib (length "a") and from the *os pubis* to *atlas* (length "b"). Ham length was measured from the anterior edge of the *Symphysis pubis* to the hock joint; circumference of the ham was measured at its widest point. The LD muscle and back fat area were measured at the loin cut between the 13th and the 14th rib by geometric procedure (Comberg, 1978) using digital planimeter "HAFF 350 E". Meat quality traits were measured in LD muscle as follows. At the slaughter line, 45 minutes *post mortem*, pH_{45} and EC_{45} values were measured, while after 24 hours of cooling pH_{24} values, and EC_{24} were taken. The measurements of pH_{45} and pH_{24} were carried out by digital pH-meter "Mettler MP 120-B", and the electric conductivity by LF-star. The color of the meat was measured with "Minolta CR-300" colorimeter at LD muscle cut after 15 minutes of blooming time and presented as CIE- L* a* b* values. Further on, 2.54 cm thick chops of LD muscle were sealed in plastic bags and frozen at -20°C for the instrumental tenderness measurements. Afterwards, they have been defrosted at 4°C for 24h, cooked in a water bath until an internal temperature of 73°C and cooled at 4°C over night. Measurements of shear force were carried out on at least four subsamples of each chop and analyzed with a TA.XTplus Texture Analyzer fitted with a Warner-Bratzler shear attachment. The mean value of maximal strength necessary for cutting of the sample was calculated with a Texture Exponent 4.0 Software (Stable Micro Systems Ltd., UK) and presented as Warner-Bratzler Shear Force (WBSF, N). A cooking loss was established from LD muscle chops used for shear force determination. It was calculated from weights taken before and after cooking and expressed as a percent. A drip loss was measured according to Kauffman et al. (1992). The ratio of fat, moisture, protein and collagen were determined on fresh sample of LD muscle by Food-Scan Lab NIT analyzer (Foss, Denmark). Statistical analysis was performed using STATISTICA 8.0 for Windows platform.

Results and discussion

The results of statistical analysis of carcass and meat quality traits as well as the chemical composition of pork samples researched in this study are shown in Table1. It can be noticed that the mean pH_{45} value measured in LD muscle of pig carcasses was 6.23, implying normal average meat quality, having in mind that the suggested values for PSE condition of pork are pH_{45}<5.8 according to Blendl et al. (1991), and pH_{45}<6.0 by Hofmann et al. (1994). Values of pH_{45} pointing at normal meat quality of heavy pigs are in accordance to those presented by Correa et al. (2006) and Uremović et al. (2006) in their study of meat quality of heavy pigs. Regarding the mean pH_{24} value (5.69), normal quality of meat could be observed as well, although according to certain authors, values indicating normal meat quality should be above 5.7 (van Laack 2000). Measurements of pH_{24} in the meat of heavy pigs were also researched by Virgili et al. (2003) and Correa et al. (2006). The design of their investigation involved different age and weight groups, but the authors found similar values to those from the present study in the oldest i.e. heaviest groups, comparable to our pigs. The mean value of electrical conductivity measured 45 minutes post mortem, EC_{45} was 4.38 mS/cm, which indicates no deviation from normal quality of meat. PSE meat is characterized by high content of free water leading to the higher electrical conductivity. According to Blendl et al. (1991), EC_{45} value of the meat with favorable meat quality should be below 5.0 mS/cm. When measured after 24 hours of chilling, mean EC_{24} value was 9.74 mS/cm, which could be considered as relatively high electric conductivity; Hoffman (1994) described pork meat with EC_{24} values higher than 9 mS/cm as unfavorable. High mean CIE-L* value (52.43) indicates slightly paler meat of the researched pigs when compared to CIE-L* values in the work of Correa et al. (2006). Average drip loss value was considerably high (8.29%), which is not desirable, especially when meat is aimed for further processing. Drip loss is positively correlated with electric conductivity, so high percentage of drip loss could be expected due to the high values of EC_{24} obtained in the present study.

No striking variability was found in the chemical composition of the analyzed meat, except for the intramuscular fat which showed rather high variability of (1.35-4.41%). Generally, chemical composition of the analyzed LD muscle samples revealed values typical for pork originated from heavier pig carcasses (Candek-Potokar et al., 1997; Latorre et al., 2004; Correa et al., 2006).

It is widely accepted that heavy pigs are less prone for PSE condition of pork which is mainly predicted by pH_{45} value. Having in mind that the variability found for this indicator was wide (range 5.45 to 6.74; standard deviation 0.32), it was clear that some of the pork included in the present study could exhibit that condition. To research such a case, pig carcasses under the study were classified into normal and PSE category according to pH_{45} criteria used by Candek-Potokar et al. (1997). These authors considered as PSE meat all of the samples with pH_{45} less or equal to 5.9. Likewise, in the present study samples with pH_{45} higher than 5.9 were grouped in the normal meat category, while ones lower than 5.9 were categorized into PSE group; the differences in carcass, meat quality traits and chemical composition between the groups are presented in Table 2.

It can be seen that 82.22% of samples were classified into category of normal meat quality, while 17.78% were categorized into PSE category. Regarding the carcass traits, statistically significant difference (p<0.05) between the two investigated groups was found only for LD muscle area. Since LD muscle surface represents the indicator of meatiness of

Table 2 Differences in carcass, meat quality traits and chemical composition of between the groups of pigs exhibiting normal (n=37) and PSE (n=8) condition of meat

Trait	„Normal"	PSE	P	Significance
Carcass traits				
Warm carcass weight (kg	152,14	155,88	0,53	n.s.
Carcass length – „a" (cm)	103,89	103,38	0,77	n.s.
Carcass length – „b" (cm)	121,11	122,75	0,52	n.s.
Ham length (cm)	40,11	39,25	0,14	n.s.
Ham circumference (cm)	85,19	86,63	0,19	n.s.
LD muscle area (cm²)	62,43	71,65	0,01	p<0.05
Back fat area (cm²)	36,38	37,35	0,79	n.s.
Meat quality traits				
*pH_{45}	6,35	5,67	0,00	p<0.01
**pH_{24}	5,67	5,81	0,15	n.s.
***EC_{45}, (mS/cm)	3,64	7,79	0,00	p<0.01
****EC_{24}, (mS/cm)	9,66	10,08	0,65	n.s.
CIE - L*	52,12	53,84	0,39	n.s.
CIE - a*	9,80	9,15	0,53	n.s.
CIE - b*	4,81	4,94	0,88	n.s.
Drip loss (%)	8,05	9,36	0,27	n.s.
Cooking loss (%)	31,53	33,53	0,01	p<0.01
WBSF (N)	60,84	58,53	0,40	n.s.
Chemical composition				
Fat (%)	2,66	2,30	0,15	n.s.
Water (%)	72,99	73,44	0,10	n.s.
Protein (%)	24,36	24,20	0,53	n.s.
Collagen (%)	0,95	1,02	0,31	n.s.

*pH_{45}-pH izmjeren 45 minuta *post mortem*; **pH_{24}-pH izmjeren 24h *post mortem*; ***EC_{45}-električna provodljivost 45 minuta *post mortem*; ****EC_{24}-električna provodljivost 24h *post mortem*; *****WBSF-otpornost na presijecanje

n.s.-nije signifikantno

*pH_{45}-pH measured 45 minutes *post mortem*;**pH_{24}-pH measured 24 h *post mortem*;***EC_{45}-electic conductivity measured 45 minutes *post mortem*;****EC_{24}-electric conductivity measured 24 h *post mortem*; ******WBSF-Warner Bratzler Shear Force

n.s.-not significant

Table 3 Effect of warm carcass weight on carcass traits, meat quality traits and chemical composition of investigated pigs

Trait	F	P	Adjusted R^2	Multiple R	Significance
Carcass traits					
Carcass length – „a" (cm)	21,81	0,00	0,32	0,58	<0,01
Carcass length – „b" (cm)	45,64	0,00	0,50	0,72	<0,01
Ham length (cm)	0,00	0,98	-0,02	0,00	n.s.
Ham circumference (cm)	8,67	0,01	0,15	0,41	<0,01
LD muscle area (cm^2)	2,11	0,15	0,02	0,22	n.s.
Back fat area (cm^2)	12,29	0,00	0,20	0,47	<0,01
Meat quality traits					
*pH_{45}	0,71	0,40	-0,01	0,13	n.s
**pH_{24}	20,36	0,00	0,31	0,57	<0,01
***EC_{45}, (mS/cm)	0,88	0,35	0,00	0,14	n.s
****EC_{24}, (mS/cm)	4,68	0,04	0,08	0,31	< 0.05
CIE - L*	0,35	0,56	-0,02	0,09	n.s.
CIE - a*	5,24	0,03	0,09	0,33	<0,05
CIE - b*	2,63	0,11	0,04	0,24	n.s.
Drip loss (%)	0,88	0,35	0,00	0,14	n.s.
Cooking loss (%)	0,35	0,55	-0,01	0,09	n.s.
*****WBSF (N)	0,31	0,58	-0,02	0,08	n.s.
Chemical composition					
Fat (%)	0,09	0,77	-0,02	0,04	n.s.
Water (%)	0,01	0,91	-0,02	0,02	n.s.
Protein (%)	1,72	0,20	0,02	0,20	n.s.
Collagen (%)	0,07	0,79	-0,02	0,04	n.s.

*pH_{45}-pH izmjeren 45 minuta *post mortem*; **pH_{24}-pH izmjeren 24h *post mortem*; ***EC_{45}-električna provodljivost 45 minuta *post mortem*; ****EC_{24}-električna provodljivost 24h *post mortem*; *****WBSF-otpornost na presijecanje

n.s.-nije signifikantno

*pH_{45}-pH measured 45 minutes *post mortem*;**pH_{24}-pH measured 24 h *post mortem*;***EC_{45}-electic conductivity measured 45 minutes *post mortem*;****EC_{24}-electric conductivity measured 24 h *post mortem*; ******WBSF-Warner Bratzler Shear Force

n.s.-not significant

heavy pigs, and there was no statistically significant difference between the observed groups in the back fat area, statistically higher muscle area indicates higher production of lean meat in animals exhibiting PSE condition. It was shown in other studies that pig carcasses with increased lean percentage often have lowered meat quality (Sonesson et al., 1998; Kralik et al, 2001; Kušec et al., 2004; Šimek et al., 2004). Differences between other carcass traits were not statistically significant.

Observing the differences between meat quality traits, statistically significant difference (p<0.01) was found between pH_{45} values, which was expected because this trait was selected as criteria for differentiation between the groups. Values pointing at possible undesirable quality of pork were found for electrical conductivity (EC_{45}) in the PSE group; they were significantly higher (p<0.01) than those from the meat characterized as normal. On the other hand, electrical conductivity measured 24 hours post mortem in the LD muscle of both pig carcass groups exhibited undesirably high values; the difference between the groups was not significant (p>0.05). Similarly, both groups of pig carcasses expressed a paler color to some extent (CIE-L*) and higher drip loss, with no significant differences between them. It is commonly known that pork with low pH has higher CIE-L* values and increased drip loss, but in the present study this was not the case because unfavorable color and drip loss occurred irrespective of pH_{45} value. Statistically significant difference (p<0.01) was found between cooking loss values. Also, both groups had values that were quite high. In chemical composition there were no statistically significant differences between the groups.

Table 3 shows relation of warm carcass weight with carcass traits, meat quality traits and chemical composition of the researched pigs obtained by F-test. It could be noticed that warm carcass weight mostly affects carcass traits positively, such as carcass length, ham circumference and back fat area, as shown previously by other authors (Cisneros et al. 1996; Virgili et al., 2003; Latorre et al., 2004; Correa et al., 2006). In the present study, ham length and LD muscle area was unaffected by warm carcass weight, although Latorre et al. (2004) found significant influence of slaughter weight on ham length, while Cisneros et al. (1996) and Virgili et al. (2003) reported significant effect of slaughter weight i.e. age on LD muscle area.

In the present study, few meat quality traits were found to be affected by warm carcass weight, namely pH_{24}, EC_{24} and CIE-a* values.

In the work of Cisneros et al. (1996) slaughter weight did not have significant effect on pH_{45}, but the opposite was true for pH_{24} and Warner-Bratzler shear force (WBSF), which is partially supported by the present study; since in our work the influence on WBSF was not significant. However, these authors also found significant influence of slaughter weight on drip loss, contrary to our results, while in the case of cooking loss the results of the mentioned authors are in agreement with ours. Latorre et al. (2004) found significant influence of slaughter weight on pH_{45}, but not for pH_{24} values, which is opposite to the results obtained in present study.

Regarding the meat color, results of our researches indicate the significant effect of warm carcass weight only on redness (CIE-a*), which is in agreement with the results of Latorre et al. (2004). In their work, slaughter weight had significant influence on the lightness of pork (CIE - L*) as well, but this could not be supported by our results. Correa et al. (2006) haven't found any influence of slaughter weight on meat quality characteristics. The authors found that only protein percentage was affected by slaughter weight which our results could not confirm. Similar to the work of Latorre et al. (2004), the results of the present study show no effect of warm carcass weight on chemical composition of pork.

Conclusion

The results in this study showed considerable variation in carcass and meat quality traits of researched heavy pigs, while chemical composition varied only in fat content. Mean pH_{45}, pH_{24} and EC_{45} values implied satisfactory meat quality, but this could not be stated for meat quality traits such as EC_{24}, drip loss and CIE L* value which were to some extent higher than expected.

Significant differences observed in LD muscle surfaces between the carcasses characterized as normal meat quality and those exhibiting PSE condition indicate increased lean production in later group. Regarding the meat quality traits, groups significantly differed in pH_{45}, EC_{45} and cooking loss, while there were no differences in chemical composition. Both groups had undesirably high values of EC_{24}, CIE-L* and drip loss, with no significant differences between the groups.

The study showed significant influence of warm carcass weight on most of the carcass measurements, more precisely on all carcass traits except of ham length and LD muscle surface. On the other hand, only few meat quality traits were found to be affected by warm carcass weight; these were: pH_{24} values, electrical conductivity (EC_{24}) and instrumental redness (CIE-a*). Chemical composition of the meat originating from Croatian heavy pigs seemed to be unaffected by warm carcass weight.

With all presented results, it can be concluded that in the rearing of heavy pigs, a special concern is needed regarding the production of high quality pork in satisfactory amounts. The meat quality traits of these pigs are often a priori taken as desirable by pig producers, which is not always the case as shown by the present study.

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