Scientific Annals of Polish Society of Animal Production - Vol. 11 (2015), No 4, 65-74

Effect of carcass conformation and fatness on beef pH and characterization of the purchase structure of domestic beef cattle

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The study analysed the effect of carcass conformation and fatness classes on beef quality and characterized the purchase structure of slaughter cattle from north-eastern Poland on the basis of data obtained from the meat industry. Quality testing was performed on randomly selected carcasses of 181 bulls, 11 cows and 57 heifers. pH of the *longissimus dorsi* muscle (LD) was measured 24 and 48 h post mortem. Characterization of purchase structure was based on a population of 13,145 slaughter cattle. pH in the LD was lowest in the heifers (5.7), higher in the bulls (5.8) and highest in the cows (5.9). Conformation classes had no effect on the pH of LD muscles in bulls or cows. In the case of heifers, the meat from class P carcasses had significantly higher pH than the meat from other classes. Fatness classes significantly affected the structure of meat quality defects. The lower the carcass fatness, the more meat had DFD defects. DFD meat was present in only about 4.5% of the cattle population (about 10% in cows and about 3% in bulls). The current purchase structure of cattle is dominated by bulls (about 44%) and cows (about 41%). Among carcass conformation classes, classes O and R account for the largest share. Carcasses of fatness class 3 were most common in all cattle categories.

KEY WORDS: beef carcasses / conformation classes/ meat quality / purchase structure

Due to high variation in conformation and fat cover, beef cattle carcasses must be divided into commercial groups called categories and classes. The main purpose of this division is to facilitate the purchase of cattle from the producer and to ensure fair pricing. To do this, the tissue composition of the body must be estimated as accurately as possible. Traditional systems for evaluating live animals do not solve this problem, because they are based mainly on a subjective method which does not ensure sufficient precision or repeatability [13, 14, 16, 21]. Modern methods are based on carcass evaluation after slaughter, a typical example of which is the EUROP system used in the European Union [15].

Cattle carcasses are classified on the basis of a visual assessment of carcass conformation, defining the degree of musculature, with a division into six classes (S, E, U, R, O, P), and fatness, with five classes (first class—low fat cover, fifth class—very high fat cover). This carcass classification system, however, is also subjective and does not guarantee sufficient comparability of assessments made within a country or between countries, or even between individuals classifying carcasses [1]. For this reason objective, automatic classification devices employing cameras have been developed. Three such systems are known: the BCC-2 developed by the Danish company SFK-Technology, the German VBS 2000, and the Australian VIAScan system [4, 9, 12].

The division of beef carcasses into EUROP classes is mainly associated with their conformation and fat cover. It is not known, however, whether this division differentiates meat quality. Opinions on this subject in the literature are scarce and inconclusive. Wajda and Daszkiewicz [19] found no significant differences between the physicochemical characteristics, chemical composition and sensory characteristics of the meat of young bulls assigned to different conformation classes. Other authors [5, 6] have shown an association between the conformation class of beef carcasses and the physicochemical characteristics of the meat. A link has also been observed between the carcass conformation class of young bulls and the fatty acid profile of the meat [11]. The highest percentage of PUFA was noted in samples taken from carcasses in the lowest conformation class, i.e. class O. The fat class of the carcasses had considerably less influence on the content of particular fatty acids. Daszkiewicz and Wajda [2] found that meat from young bull carcasses assigned to higher fat classes had greater fat content and a greater degree of marbling. They also observed higher acidity in the meat of carcasses with the highest fat cover. Another study by the same authors [3] showed that the meat of heifers in the O3 class, indicating higher fat content, had better sensory characteristics than the meat of the O2 class.

The aim of the study was to investigate the effect of the conformation and fat classes of beef carcasses on the acidity of meat and to determine the purchase structure of beef cattle in the meat industry.

Material and methods

The study was conducted in the north-eastern region of Poland, which is representative of the country in terms of purchase of slaughter cattle. The purchase structure was characterized on the basis of data on the number of animals slaughtered in the third quarter of 2011, taking into account categories of cattle and classes of conformation and fat cover. The population analysed was mainly represented by Black-and-White Lowland cattle, with crossbreeds constituting a few percent in the categories of young bulls and heifers.

Among the slaughtered cattle 181 bull carcasses, 111 cow carcasses and 57 heifer carcasses were randomly selected for analysis, involving measurement of pH in the *longissimus dorsi* (LD) muscle 24 h and 48 h post mortem. The measurements were made with a Radiometer PHM 80 with a combination electrode. The results of the pH measurements were used to determine the quality of the meat. The animals were slaughtered after a 24-hour rest period. During this time they were not fed but had continual access to water. The differences between mean pH values for each carcass class were determined by one-way analysis of

variance, and the significance of differences between means was verified on the basis of Student's t-statistic used to test LSD (Least Significant Differences).

Results and discussion

The beef cattle purchase structure is fairly representative for the country, as it includes cattle purchased from several voivodeships of the north-eastern and central region. In total 13,143 cattle were purchased and slaughtered (Tab. 1), broken down as follows:

– category A young bulls up to 24 months old – 5,666 (43.11%)
– category B bulls over 24 months old – 122 (0.93%)
– heifers – 1,988 (15.13%)
– cows – 5,367 (40.83%)

The beef cattle categories represented in the highest numbers were young bulls and cows, with cows accounting for 40% of the population of purchased cattle. Age category A, representing animals up to 24 months old, was dominant among bulls and accounted for about 43% of purchased cattle. Older bulls in category B made up a very small portion of the animals purchased (about 1%). Heifers are a category that is systematically decreasing in cattle purchases. In the 1980s their share was still similar to that of young bulls and steer [18]. As production of steer is less profitable they are no longer purchased, and the percentage of heifers was about 15%. The low percentage of heifers in the slaughter structure is strongly influenced by export of live calves, which in 2012 numbered about 120,000 animals, i.e. about 10% of their population [23].

According to data from the Ministry of Agricultural and Rural Development [23], the slaughter structure in Poland in 2013 was as follows: bulls – 53.1%, cows – 325%, and heifers – 14.3%. These data indicate a growing proportion of young bulls and a decreasing proportion of cows in the industrial slaughter of beef cattle in the country.

The largest carcass conformation class in all categories of cattle was class O, with a share ranging from about 52% in heifers to about 58% in cows, while the smallest was class E, with a share ranging from only 0.11% of carcasses in the cow category to 2.46% of carcasses of category B bulls. The poorest conformation class, P, was least common among the heifer carcasses (0.3% of the population) and most common among the cow carcasses (about 23%). Class U was represented by a few percent each of carcasses of heifers and young bulls (about 3-6%) and only 0.61% of cow carcasses. Class R was a fairly large group of carcasses, second after class O (from about 18% to 44% depending on the category). Similar percentages of conformation classes were noted in 2009 by Wajda and Borzuta [18]; the percentages in the young bull category were as follows: class E – 0.2%, class U – 3.2%, class R – 28.0%, class O – 60.3% and class P – 8.3%. The authors emphasize that in countries with a large proportion of beef cattle breeds the purchase structure is much more favourable, e.g. in Italy 17.7% of young bull carcasses are assigned to class E, 48.5% to class U and only 4% to class O.

A characteristic feature of the carcasses of all cattle categories was an increase in carcass weight as the conformation class improved. The mean carcass weight increased in individual cattle categories, from class P to class E, as follows (Tab. 1):

– category A young bulls – from 232 to 460 kg
– category B bulls – from 260 to 471 kg

– heifers – from 166 to 350 kg
– cows – from 226 to 577 kg

The mean carcass weight was also dependent on the fat class and increased with fat content as follows (Tab. 1):

– category A young bulls – from 284 kg (class 1) to 443 kg (class 4)
– category B bulls – from 320 kg (class 1) to 388 kg (class 3)
– heifers – from 195 kg (class 1) to 320 kg (class 4)
– cows – from 214 kg (class 1) to 448 kg class 5)

The association of beef carcass weights with their class is confirmed by literature data. Wajda and Daszkiewicz [20] noted the following mean carcass weight in young bulls of different fat classes: class 1 – about 220 kg, class 2 – about 317 kg and class 3 – about 343 kg.

Beef carcass classes are a factor influencing price. The data presented in Table 1 show that in all cattle categories there was a fixed relationship between the purchase price and the conformation class. The higher the conformation class, the higher the price, and the difference in price between the highest and lowest classes was 5.06 PLN/kg in category A young bulls, 2.81 PLN/kg in category B bulls, 3.68 PLN/kg in cows and 6.68 PLN/kg in heifers. The fat class has a smaller impact on carcass price. The price difference between the highest and lowest fat classes was 0.50 PLN/kg in category A young bulls, 0.63 PLN/kg in category B bulls, 0.97 PLN/kg in cows, and 3.24 PLN/kg in heifers, in favour of carcasses with higher fat cover. The mean carcass price, as the quotient of the value of all animals purchased and the number of animals purchased, was as follows for the categories of cattle:

– category A young bulls – 12.06 PLN/kg
– category B bulls – 11.37 PLN/kg
– cows – 10.48 PLN/kg
– heifers – 10.22 PLN/kg

The highest price was obtained for the category A young bulls, and the lowest for the heifers. It is noteworthy that the price of the heifer carcasses, which supply meat of the best quality, is similar to the price of cow carcasses. Śmiecińska and Wajda [17] point out that the meat of heifers is of better quality than that of young bulls. It has a lighter colour and higher acidity. However, unlike young bull carcasses, heifers usually have higher fat cover and more intramuscular fat [17]. This leads to a worse economic effect in cutting and trimming of the carcasses.

An interesting question is the problem of linking the prices of different categories and classes of beef carcasses to the quality of the meat. Several decades ago a study by Krzywicki and Wichłacz [10] showed that a very important factor determining the quality of beef, particularly its tenderness and water-holding capacity, is pH. The degree of acidity of the meat is also linked to its colour. Another study by Wichłacz and Krzywicki [22] showed that the correlation coefficient between the lightness of the colour of the rump cut and its pH is r=0.67.

Analysis of the data presented in Table 2 indicates that the pH of the *longissimus dorsi* muscle did not depend on the carcass conformation class of the young bulls and cows. In the case of the heifers, however, pH was found to be dependent on the conformation class; for example, the inferior class O had a higher pH than class U, both 24 and 48 hours after slaughter ($P<0.05$). Taking into account the results for all conformation classes, the following pH values were obtained for the cattle categories: bulls – 5.95 and 5.82, cows – 6.16 and 5.88, and heifers – 6.02 and 5.72.

Table 1
Purchase structure of cattle in the meat industry of north-eastern Poland

Category	Conformation or fatness class	Share in population		Mean carcass weight (kg)	Mean carcass price (PLN/kg)
		head	%		
Bulls of category A	E	41	0.72	459.8	13.13
	U	256	4.52	406.0	12.86
	R	2126	37.52	358.2	12.48
	O	3218	56.79	316.8	11.66
	P	25	0.44	232.2	8.07
	1	553	9.76	283.8	11.72
	2	2031	35.85	317.1	11.76
	3	3078	54.32	359.6	12.47
	4	4	0.07	443.1	13.32
	5	0	0	–	–
Bulls of category B	E	3	2.46	471.3	11.50
	U	7	5.74	463.8	12.30
	R	43	32.25	360.3	11.78
	O	67	54.92	327.6	10.99
	P	2	1.64	259.5	8.69
	1	29	23.77	319.7	11.09
	2	49	40.16	332.0	11.62
	3	44	36.07	388.2	11.72
	4	0	0	–	–
	5	0	0	–	–
Cows	E	6	0.11	577.4	12.08
	U	33	0.61	437.6	11.92
	R	972	18.11	324.8	11.17
	O	3117	58.08	280.5	10.43
	P	1239	23.09	225.9	8.40
	1	549	10.23	213.9	9.72
	2	1214	22.62	240.2	10.22
	3	3305	61.58	294.3	10.75
	4	295	5.50	354.0	11.46
	5	4	0.07	448.1	10.69
Heifers	E	3	0.15	349.7	11.89
	U	57	2.87	334.1	11.39
	R	880	44.27	289.4	10.94
	O	1042	52.41	249.2	9.97
	P	6	0.30	166.2	5.21
	1	18	0.91	195.1	7.51
	2	216	10.87	231.6	9.35
	3	1561	78.52	269.2	11.10
	4	193	9.71	319.6	10.75
	5	0	0	–	–

Among the cattle categories the final acidity of the meat 48 h after slaughter was highest for the heifers (about 5.7), somewhat lower for the bulls (about 5.8), and lowest for the cows (about 5.9). This pH distribution resulted in a marked difference in the quality stru-

Table 2
Mean pH of m. *longissimus dorsi* according to category and carcass conformation class

Category		Class E		Class U		Class R		Class O		Class P		Significant differences P
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Bulls	pH_{24}	5.90	0.15	5.97	0.14	5.93	0.08	6.00	0.08	–	–	NS
	pH_{48}	5.77	0.18	5.83	0.11	5.82	0.12	5.86	0.07	–	–	NS
	n	10	–	11	–	65	–	95	–	–	–	
Cows	pH_{24}	–	–	–	–	6.16	0.12	6.15	0.13	6.16	0.18	NS
	pH_{48}	–	–	–	–	5.91	0.05	5.83	0.11	5.90	0.14	NS
	n	–	–	–	–	24	–	58	–	29	–	
Heifers	pH_{24}	–	–	5.83^{a}	0.15	6.10^{b}	0.13	6.13^{b}	0.16	–	–	0.05
	pH_{48}	–	–	5.65^{a}	0.11	5.72^{ab}	0.12	5.79^{b}	0.09	–	–	0.05
	n	–	–	10	–	21	–	26	–	–	–	

$\bar{x}$ – mean value; SD – standard deviation
a, b – means with different superscript letters are significant at P≤0.05
NS – non-significant differences

cture of the meat between cattle categories, as shown in Table 3. The highest percentage of DFD meat was noted in the cows (about 10%). The percentage was three times lower in bulls (about 3%) and zero in the heifers. A certain differentiation of quality structure can also be observed in different carcass conformation classes (Tab. 4). While DFD meat was observed in about 3-6% of carcasses in classes O to E, in class P it was noted in about 13% of carcasses. The effect of cattle category on the pH of meat in the present study confirms the results of a previous study by Grześkowiak et al. [7], in which the mean pH_{48} in the LD was 6.31 in young bulls and 5.80 in heifers. On the other hand, no effect of conformation on the pH of meat was found in a study by Wajda and Daszkiewicz [19].

An effect of fat classes on the pH of meat was observed only for class 1, with the lowest fat cover, in which lower acidity was noted (P≤0.05) than in classes 2, 3 and 4. (Tab. 5).

Table 3
Quality structure of beef carcasses according to cattle category

Category	n	Percentage of carcasses with pH_{48} ≤5.8	Percentage of carcasses with pH_{48} 5.9-6.1	Percentage of carcasses with pH_{48} ≥6.2
Bulls	181	48.07	49.17	2.76
Cows	111	49.54	40.55	9.91
Heifers	57	61.40	38.60	0.00

Tabela 4
Quality structure of beef carcasses according to conformation class (total bulls, cows and heifers)

Conformation class	n	Percentage of carcasses with $pH_{48} \leq 5.8$	Percentage of carcasses with pH_{48} 5.9-6.1	Percentage of carcasses with $pH_{48} \geq 6.2$
E i U	31	55.56	38.89	5.55
R	110	57.26	37.61	5.13
O	179	47.28	50.00	2.72
P	29	43.33	43.33	13.34

On the other hand, fat classes fairly significantly differentiated the quality structure of meat (Tab. 6). It was found that as the fat cover of the carcasses decreased, the percentage of meat with the DFD quality defect increased and that of meat with a favourable final pH decreased. DFD meat was noted in 12% of carcasses in class 1, about 4% in class 2, about 1% in class 3, and none in class 4. Meat with a favourable pH_{48}, i.e. ≤5.8, was noted in about 70% of carcasses in class 4 but in only 20% in class 1.

To sum up, the final acidity of the *longissimus dorsi* muscle 48 h after slaughter was highest in the heifers (pH about 5.7), lower in the bulls (pH about 5.8) and the lowest in the cows (pH about 5.9). Conformation classes had no effect on the pH of the meat of the bulls and cows, but an effect was noted in heifers, in which meat of the poorest class P had a higher pH than the remaining classes. Carcass fat classes fairly significantly differentiated the quality structure of the meat. The lower the fat cover, the more meat had the DFD quality defect. In industrial slaughter of cattle in 2011 a relatively small percentage of meat had DFD quality defects. DFD meat was noted on average in about 4.5% of the

Table 5
Mean pH of m. *longissimus dorsi* according to category and carcass fatness classes

Category		Class 1		Class 2		Class 3		Class 4		Significant differences P
		$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	
Bulls	pH_{24}	6.13^{a}	0.21	6.00^{ab}	0.13	5.94^{b}	0.21	5.90^{b}	0.14	0.05
	pH_{48}	5.97^{a}	0.18	5.86^{ab}	0.12	5.81^{b}	0.19	5.80^{b}	0.11	0.05
	n	10	–	91	–	71	–	9	–	
Cows	pH_{24}	6.31^{a}	0.15	6.09^{b}	0.23	6.17^{b}	0.15	6.02^{b}	0.13	0.05
	pH_{48}	5.99^{a}	0.14	5.81^{b}	0.18	5.86^{b}	0.09	5.86^{b}	0.11	0.05
	n	18	–	23	–	57	–	13	–	–
Heifers	pH_{24}	–	–	6.13	0.18	6.13	0.16	5.99	0.14	NS
	pH_{48}	–	–	5.82	0.11	5.75	0.11	5.72	0.13	NS
	n	0	–	11	–	34	–	12	–	–

$\bar{x}$ – mean value; SD – standard deviation
a, b – means with different superscript letters are significant at P≤0.05
NS – non-significant differences

Table 6
Quality structure of beef carcasses according to fatness class (total bulls, cows and heifers)

Fatness class	n	Percentage of carcasses with $pH_{48} \leq 5.8$	Percentage of carcasses with pH_{48} 5.9-6.1	Percentage of carcasses with $pH_{48} \geq 6.2$
1	28	20.00	68.00	12.00
2	125	42.52	53.54	3.94
3	162	53.97	44.89	1.14
4	34	70.37	29.63	0.00

population, including about 10% of cows and about 3% of bulls. In the purchase structure of cattle, bulls (about 44% of the population) and cows (about 41%) were dominant. Among carcass conformation classes the highest share was noted for class O (on average 52-58%, depending on the category) and class R (from 18% in cows to 44% in heifers). A fraction of a percentage of carcasses were assigned to classes E and P, except for cows, whose percentage in class P was as high as 23%. In all cattle categories carcasses in fat class 3 were most numerous (from about 40% to about 78%), while classes 5 and 4 had the fewest carcasses. Carcass conformation classes are a factor influencing price. In all cattle categories, the better the conformation class, the higher the purchase price, and the differences in prices between the highest and lowest classes were about 3-7 PLN/kg. The fat cover class had less effect on price (differences from about 1 PLN to about 3 PLN/kg between the first and fifth fat class).

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