Meat quality defined based on pH and colour depending on cattle category and slaughter season

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ABSTRACT: The studies were carried out on 614 animals slaughtered in winter and summer seasons. After slaughter and post-slaughter processing the carcasses were evaluated according to EUROP system. The meat pH and its colour were determined in *m. longissimus thoracis* after 48 hours of chilling. A significant effect of cattle category, season of slaughter and interactions between them on meat pH was found. High pH values were observed mainly in the summer season in the groups of young bulls (A) (6.1) and bulls (B) (6.07). Slightly lower values 5.94 and 5.65, respectively, were observed in both above-mentioned groups in winter. Meat collected from heifers was characterized by proper pH in both analysed seasons whereas meat obtained from cows had pH values above 5.8, independently of the season of slaughter. The differences in colour lightness L^* observed among all analysed cattle categories were statistically highly significant ($P < 0.0001$). The brightest red meat was obtained from heifers and the darkest from cows. The differences between young bulls and bulls in the same slaughter seasons were not large despite considerable variation in the age of slaughtered animals, especially in the summer season. Distinctly higher values of L^* (brighter red meat) were found in the winter season in all cattle categories excluding meat from cows in which L^* in summer was slightly higher than in winter. The differences in L^* between seasons as well as the interaction of cattle category × slaughter season were statistically highly significant ($P < 0.0001$). For the remaining colour parameters (a^*, b^*) higher values were also observed in winter compared to summer in all cattle categories. The highest values of a^* and b^* were found in bulls.

Keywords: cattle; *longissimus thoracis muscle*; slaughter season; meat pH and colour

Recently not only the quantity but also the quality of produced milk and beef has become increasingly important. That situation has resulted from the increased consciousness and demand of consumers who expect food characterized by special dietetic or health properties (Brunso et al., 2005). The quality of beef is affected by many factors but the most import are type, breed, sex, feeding, growth rate and animal handling associated with marketing and slaughter of animals (Beltrán et al., 1997; Pipek et al., 2003; Žgur et al., 2003; Bartoň et al., 2007; Mach et al., 2008).

The sex significantly influences carcass and meat quality. Bull carcasses are characterized by higher meat content with simultaneous lower content of fat compared to heifer carcasses. Contrary, heifers are more fattened with lower share of bones. However, meat obtained from bulls is often characterized by improper quality parameters especially high pH and dark colour, which negatively affects its technological properties and limits its suitability to culinary meat production (Węglarz et al., 2002; Kögel, 2005; Mach et al., 2008).

A high share (up to 50%) of culled dairy cows in slaughtered cattle production considerably influences beef quality in Poland. Meat from beef cows is defined as red meat. In some countries red meat has higher prices compared to pink meat from young slaughter cattle. In Poland the slaughtered cows belong mainly to Black-and-White breed with different HF blood share. Consequently, the obtained carcasses are characterized by lower slaughter and quality parameters. Despite the development of beef cattle breeding in Poland in recent years its share in slaughtered cattle production (less than 1%) is still negligible. Considering the breeding structure of the cattle population in Poland characterized by a high share of dairy breeds, which is found also in other countries, the most adequate method of the improvement of slaughtered cattle quality is commercial crossing of dairy cows with beef bulls (Węglarz, 1997; Polách et al., 2004; Bartoň et al., 2007).

According to many studies the ultimate pH and meat colour are the most important indices of meat quality. They should be used in a standard evaluation of meat and especially in choosing meat for ageing process. The same quality parameters are taken into account in the evaluation of carcasses and meat intended for export (Wulf et al., 1997; Wulf and Wise 1999; Page et al., 2001; Gońi et al., 2007). When assessing meat, a consumer pays a great attention to its colour, which, as a visual impression, is induced mainly by the presence of pigments but it also depends on tissue composition and meat structure. Hence, the colour of fresh meat is an important quality parameter that determines a consumer's response and decision to buy or not to buy that product at retail.

Meat quality is significantly affected by pre-slaughter factors. Atmospheric conditions in the pre-slaughter period, and especially those causing an additional stress for animals can be important. Seasonal changes in temperature can affect the level of glycogen in muscles after slaughter and the ultimate pH, and consequently the quality of meat. An increase in glycolysis results from excessive excitement, starving and stress caused by ambient temperature, which in turn leads to high post-mortem pH values and consequently meat colour is influenced (Kreikemeier et al., 1998; Abril et al., 2001; Honkavaara et al., 2003). The problem of seasonal changes in meat quality caused by temperature stress was studied by many authors (Fabiansson et al., 1984; Jones and Tong, 1989; Mitlöhner et al., 2002; Kadim et al., 2004). Davis and Mader (2001) reported that physiological stress could occur in cattle at the temperature even only slightly higher than 20°C.

Stress is the most frequently identified factor in the pre-slaughter handling of animals. It negatively affects meat quality, which results in economic losses. Stress and energy expenditures in pre-slaughter period cause the depletion of muscle glycogen reserves and, consequently, the insufficient post-mortem production of lactic acid. Low acidity in the ageing period results in the change of colour, structure, taste and tenderness of meat (Silva et al., 1999; Immonen et al., 2000; Honkavaara et al., 2003).

In animals exposed to pre-slaughter stress DFD (Dark-Firm-Dry) meat, characterized by dark colour at the muscle cut surface, often occurs. It leads to considerable financial losses in meat industry. Dark meat is more dry compared to normal meat and has limited durability. Meat of high quality has ultimate pH at the range of 5.4–5.6. At pH > 5.8 a decrease in meat delicacy as well as a possibility of maintaining good quality during cooling is observed. High pH is improper for sorting, confectioning and vacuum packaging of meat.Moreover, meat of a high ultimate pH can be characterized by gummy structure, increased water-holding capacity and decreased specific taste (Pipek et al., 2003; Villarroel et al., 2003).

The aim of the present study was to evaluate the slaughter quality of young bulls, bulls, cows and heifers according to post-slaughter EUROP classification and to assess meat quality obtained from these cattle categories considering the season of slaughter.

MATERIAL AND METHODS

The data were collected from a specialised cattle slaughterhouse where about 100 animals are slaughtered every day. The studied material consisted of 614 animals of Black-and-White breed with a high share of Holstein-Friesian breed. The animals originated from farms with similar feeding and management systems. Cows and heifers were kept in free stall barns while the males were kept in tie stalls. Throughout a year the animals received preserved feeds. The feeding rations were based on wilted grass silage and maize silage supplemented with a small amount of concentrates. The time of cattle transport from farms to slaughterhouses was approximately 4–6 hours. The males were tied du-ring transport. After arrival in the slaughterhouse all animals were placed in the lairage where

Table 1. The number of animals in carcass categories evaluated according to slaughter season

Season	Beef cattle carcass category				Total
	A	B	D	E	
Summer	69	34	158	42	303
Winter	37	62	159	53	311
Total	106	96	317	95	614

A = young bulls; B = bulls; D = cows; E = heifers

they stayed 8 to 12 hours. Cows and heifers were kept in groups of 6–10 animals in pens whereas the males were tied. The pens were straw bedded and the animals had permanent access to water. The material under study consisted of 614 animals. They were divided into five categories according the EUROP classification of cattle carcasses: young bulls – until the age of 24 months (A), bulls – above 24 months of age (B), cows – females with progeny (D), heifers – females without progeny (E). The number of animals in particular categories, divided according to the season of slaughter (winter – average daily temperature –7°C, summer – average daily temperature 18°C), is presented in Table 1.

After post-slaughter processing of carcasses their quality evaluation (classification of conformation and fatness according to EUROP system) and weighing were carried out. The pH was measured in the *m. longissimus thoracis* (between the 11th and 13th thoracic vertebra) 48 h *post-mortem* using a MATTHÄUS, pH-STAR CPU (Matthäus, Pöttmes, Germany); pH-meter with a glass electrode standardized for pH 4.6 and 7.0. The pH-meter automatically corrected pH values, taking into account the muscle temperature.

Meat colour was determined in the fresh cross-section of *m. longissimus thoracis* (*LT)* 48 hours after slaughter using a Minolta Chroma Meter CR-310 (Minolta Co., Ltd., Japan), with a colour measuring area of 50 mm in diameter in CIE colour system $L^*a^*b^*$, where the L^* value designates lightness, ranging from 0 for black to 100 for ideal white, whereas a^* and b^* are colour coordinates ($+a^*$ = redness, $-a^*$ = green, $+b^*$ = yellow, $-b^*$ = blue).

The meter was calibrated using a Minolta calibration ceramic tile (L^* = 93.8, a^* = 0.3136, b^* = 3192).

Also, colour intensity/saturation (C^*) and h^* index were calculated as follows:

$$C^* = \sqrt{(a^*)^2 + (b^*)^2}$$

and

$$h^* = \arctan\left(\frac{b^*}{a^*}\right)$$

The obtained values were analysed in relation to cattle category and season of slaughter as well as to the interactions between them. For statistical evaluation two-way analysis of variance using the SAS package (Cary, NC, USA) was performed. The significance of the studied effects was estimated by means of *F*-test and the significance of the differences among cattle categories within slaughter seasons was evaluated by the multiple range test. Additionally, Pearson's correlations between slaughter traits and meat quality traits were estimated.

RESULTS AND DISCUSSION

The results of the evaluation of slaughter values depending on beef cattle category and slaughter season are presented in Table 2. The slaughter season did not affect significantly the analysed post-slaughter indices except carcass conformation (P = 0.0060). Better conformation (muscularity) of carcasses from young bulls (A), bulls (B) and heifers (E) was found in the summer season whereas in cows (D) higher values were observed in the winter season. The improvement of conformation of bull carcasses (B) compared to young bulls (A) suggests that young bulls were slaughtered at too low body weight (520 kg on average), before reaching slaughter maturity. Higher mean slaughter and carcass weights of bulls (B) compared to young bulls (A) resulted in higher grades of carcass conformation evaluated according to the EUROP classification system, 4.97 and 4.36, respectively,

Table 2. Parameters of slaughter value depending on cattle category and slaughter season

Trait		Summer					Winter					P > F		
		cattle category				multiple range test	cattle category				multiple range test			
		A	B	D	E		A	B	D	E		season	category	season × category
Age (days)	mean	563.48	936.76	2 581.27	688.50	A: B, D*, E; B: D*, E; D: E*	579.11	689.68	2 364.99	605.06	D: A*, B*, E*	0.0889	< 0.0001	0.5924
	SD	187.26	299.47	1 090.59	215.30		91.01	203.17	1 150.90	284.97				
Body weight at slaughter (kg)	mean	523.72	635.62	498.84	451.34	E: A*, B*, D; B:A*, D*	520.49	589.60	512.62	430.43	A: B*E*; B: D*, E*; D: E*	0.136	< 0.0001	0.0731
	SD	114.16	110.78	95.05	71.80		98.17	133.59	92.91	85.77				
Hot carcass weight (kg)	mean	278.13	340.72	259.91	238.34	E: A*, B*, D*; B: A*, D*	275.30	314.83	267.69	227.33	A: B*, E*; B: D*, E*; D: E*	0.1278	< 0.0001	0.0684
	SD	62.78	61.69	51.67	39.12		54.67	74.80	51.95	47.62				
Hot dressing percentage (%)	mean	53.03	53.55	52.03	52.77	A:B*, D*, E; B: D*, E* D: E*	52.81	53.28	52.10	52.70	A: B, D*; B: D*, E; D: E	0.1356	< 0.0001	0.2668
	SD	0.66	0.54	0.59	0.72		0.83	1.03	0.99	1.24				
Conformation score**	mean	4.36	4.97	3.64	4.76	E: A*, B, D*; B: A, D*	3.70	4.21	3.77	4.36	NS	0.0060	< 0.0001	0.0418
	SD	1.39	1.06	1.35	0.98		1.54	2.03	1.91	1.93				
Fatness score***	mean	2.33	2.50	2.23	2.67	E: A, D	2.00	2.52	2.31	2.40	A: B, D, E	0.0959	0.0015	0.0749
	SD	2.16	2.49	2.25	2.07		2.13	2.16	2.79	2.73				

A:B, D* – category A differs from B at the level of $P < 0.05$; category A differs from D at the level of $P < 0.01$

**15-point scale: 15 = E+ (very good conformation), ... , 1 = P – (very poor conformation)

***5-point scale: 5 = very fat, ..., 1 = very lean

A = young bulls, B = bulls, D = cows, E = heifers

Table 3. Parameters of the colour and pH of LT muscle depending on cattle category and slaughter season

Trait		Summer cattle category A	B	D	E	Summer multiple range test	Winter cattle category A	B	D	E	Winter multiple range test	P>F season	category	season × category
pH	mean	6.10	6.07	5.89	5.61	A: D*, E*; B: D*, E*; D: E*	5.94	5.65	5.88	5.63	A: B*, E*; D: B*, E*	< 0.0001	< 0.0001	<0.0001
	SD	0.22	0.22	0.19	0.13		0.20	0.31	0.22	0.18				
L^*	mean	37.40	37.33	36.81	38.75	E: A, B, D*	39.74	39.61	36.47	41.41	A: D, E*; B: D, E* D: E*	< 0.0001	< 0.0001	< 0.0001
	SD	1.38	1.32	1.85	2.46		1.63	2.71	2.38	1.70				
a^*	mean	13.44	12.58	13.34	11.80	A: E; D: E	14.10	17.26	13.65	12.83	B: A*, D*, E*	< 0.0001	< 0.0001	< 0.0001
	SD	2.07	2.06	2.76	2.84		2.11	3.46	3.26	1.49				
b^*	mean	3.76	3.15	3.21	3.82	E: A*, B*, D; D: B	3.25	5.11	4.12	2.02	A: B*, D, E*; B: D*, E*; D: E*	< 0.0001	0.0040	< 0.0001
	SD	0.91	1.06	1.34	1.89		1.12	1.65	1.88	1.15				
C*	mean	13.96	12.97	13.72	12.40	E: A, D	14.47	18.01	14.26	12.99	B: A*, D*, E*	< 0.0001	< 0.0001	< 0.0001
	SD	2.03	1.99	2.76	3.00		2.12	3.59	3.39	1.47				
h*	mean	0.27	0.25	0.24	0.31	E: A*, B*, D; B: A, D	0.23	0.29	0.29	0.16	A: B*, D, E*; B: E*; D: E*	< 0.0001	0.0060	< 0.0001
	SD	0.07	0.06	0.10	0.13		0.08	0.08	0.12	0.09				

*L** = lightness; *a** = redness; *b** = yellowness; C* = chrome; h* = hue

A:B, D* – category A differs from B at the level of $P < 0.05$; category A differs from D at the level of $P < 0.01$

in the summer season, and 4.21 and 3.70 in the winter season. These results show that the fattening of young cattle carried out in a semi-intensive system and finished at too low final body weight negatively influenced the slaughter value of carcasses (most carcasses were classified as O and P conformation classes). According to Oprządek et al. (2007) young bulls of Holstein-Friesian breed are characterized by the best carcass parameters when they are slaughtered at the weight of 600–700 kg. Also Litwińczuk et al. (2006) found that an increase in slaughter weight of heifers and bulls was accompanied by the improvement of carcass conformation class and higher dressing percentage.

The effect of cattle category on slaughter value was statistically highly significant, which seems to be fully justified. Generally, no statistically significant interactions between the slaughter season and cattle category for the studied traits of slaughter value were found.

The parameters of meat colour and pH for the analysed cattle category and slaughter season are shown in Table 3. Statistically significant effects of slaughter season and cattle category as well as the interactions between them on meat pH were found. High values of pH were observed in young bulls (A) and bulls (B), especially in the summer season. Slightly lower meat pH in young bulls and bulls was reported in the winter season. However, the mean values of meat pH in these categories were high and amounted to 6.1 and 6.07, respectively, in the summer season and to 5.94 and 5.65 in the winter season. Higher pH observed in summer can result from the fact that males are more sensitive to different stress factors, including high air temperature. Meat of heifers had proper pH values in both analysed seasons. However, at extremely high temperatures of West Texas an increased frequency of dark-cutting carcasses in heifers was found by Mitlöhner et al. (2002). Meat of cows was characterized by pH values higher than 5.8, independently of the slaughter season. Similarly to the results of this study, Page et al. (2001) obtained distinct differences in pH of meat collected from different cattle categories, which indicated a significant effect of sex on the ultimate pH values.

Results of Kadim et al. (2004) proved a significant effect of environment on beef quality. They reported that ultimate meat pH in the winter season was 5.54 whereas in the hot season it was 6.24. Kreikemeier (1998) found that an increased amount of dark-cutting included lighter-weight cattle and increased holding time at the slaughterhouse before slaughter. While studying the influence of different pre-slaughter factors on beef quality, Mounier et al. (2006) concluded that beef obtained on cold days was characterized by lower ultimate pH compared to beef collected in the hot season.

Large differences among cattle muscles in colour stability during post-slaughter cooling storage are observed. The highest colour stability was found in *m. longissimus thoracis* (*LT)*, moderate stability in *m. semimembranosus*, intermediate stability in *m. gluteus medium*, and the lowest stability *m. psoas major* (McKenna et al., 2005). Therefore *LT* is commonly used to evaluate meat colour. In the present study meat colour was also evaluated in this muscle.

The differences in colour lightness L^* observed among the analysed cattle categories were statistically highly significant ($P < 0.0001$). The brightest red meat was obtained from heifers and the darkest meat from cows. In the same slaughter seasons the differences in L^* between young bulls and bulls were not large, although the animals differed considerably in age at slaughter. This was observed especially for animals slaughtered in the summer season. Distinctly higher values of L^* (lighter meat) were found in the winter season for all cattle categories excluding meat of cows in which L^* in summer was slightly higher than in winter. The differences in L^* between seasons as well as in the interaction cattle category × slaughter season were statistically highly significant ($P < 0.0001$). For the remaining colour parameters (a^*, b^*) higher values were also observed in winter than in summer in all cattle categories. The highest values of a^* and b^* were found in bulls. Similar relationships between the values of colour parameters L^*, a^* and b^* evaluated in different slaughter seasons were reported by Kadim et al. (2004). When analysing beef quality in four seasons of the year in South Korea, Kim et al. (2003) also found a significant effect of the season on meat colour parameters. However, contrary to the results reported here the lowest values of L^*, a^* and b^* were observed in winter.

In the present study the effects of cattle category, slaughter season and interaction between them on colour intensity/saturation C^* and h^* proved to be significant. Higher values of these parameters were estimated in the winter season compared to the summer season, especially in young bulls and bulls. Despite the expected higher heme pigment content in the muscles of older animals compared to young-

Table 4. Coefficients of Pearson's correlation between the analysed traits of slaughter value, meat pH and colour parameters

Trait	Body weight	Hot carcass weight	Hot dressing percentage	Carcass conformation	Carcass fatness	pH
pH	0.01	0.00	0.04	–0.15	–0.06	–
*L**	–0.01	0.01	0.23[a]	0.15[a]	0.08	–0.24[a]
*a**	–0.04	–0.04	–0.06	–0.23[a]	–0.05	–0.29[a]
*b**	–0.14[a]	–0.15[a]	–0.21[a]	–0.31[a]	–0.10	–0.24[a]
*C**	–0.04	–0.04	–0.06	–0.23[a]	–0.05	–0.29[a]
*h**	–0.17[a]	–0.17[a]	–0.22[a]	–0.30[a]	–0.12[a]	–0.20[a]

[a]$P < 0.05$

er ones the value of *L** was probably more distinctly affected by meat pH than by the age of animals. Similarly to our results, Fabiansson et al. (1984) found that the season noticeably affected colour parameters of beef. They observed the highest incidence of dark-cutters from May to August.

The correlation coefficients between slaughter value parameters and colour and pH indicate that the relationships were poor or none (Table 4). The highest correlations were found between carcass conformation and the analysed parameters of meat quality (from 0.15 to 0.31). All of them were negative except the value for meat lightness (*L**). The correlations between meat pH and all colour parameters proved to be significant. Their values ranged from –0.20 to –0.29, which indicated that the increase of meat pH caused the deterioration of all colour parameters. Slightly higher correlation coefficients between meat pH and colour lightness *L** (–0.40) were observed by Page et al. (2001). Kadim et al. (2004) found higher correlations between meat pH and parameters of its colour: for *L** –0.46, *a** –0.73, *b** –0.51 in the hot season and –0.47, –0.49 and –0.30, respectively, in the winter season. Lower values of correlations between meat pH and all colour parameters obtained in the present study can probably result from relatively low variation in meat pH values estimated for the analysed animal categories.

The correlation between dressing percentage and the coefficient of lightness *L** was positive (0.23) while the correlations between dressing percentage and *b** and *h** were negative and amounted to –0.21 and –0.22, respectively. The above-mentioned relationships were significant. Similarly, the significant correlations were estimated between carcass conformation and all colour parameters. The presence of the relationship between carcass conformation and meat pH was reported by Mach et al. (2008). They estimated a higher frequency of carcasses with the poorest conformation in the group with high meat pH > 5.8. They also proved that the increase of fatness resulted in a considerable decline of the frequency of meat with high pH.

The percentage distribution of pH values in meat collected from cattle slaughtered in the analysed seasons is presented in Figures 1 and 2. The values considered as proper, i.e. lower than 5.8, were more frequent in the winter season compared to summer. Meat from only 21.0% of young bulls was characterized by proper pH. In the remaining cattle categories the respective values were 68.75% for bulls, 46.75% for cows and 72.5% for heifers. In the summer season the share of meat with proper pH was higher than in the winter season only in heifers – more than 86%. In the remaining cattle

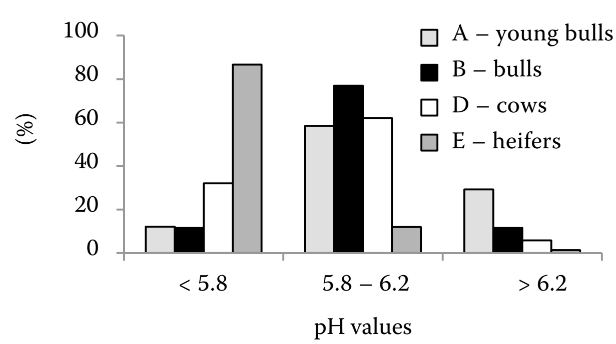

Figure 1. Percentage distribution of pH values in meat of different categories of cattle slaughtered in the summer season
(A, B, D, E) cattle categories according to EUROP system

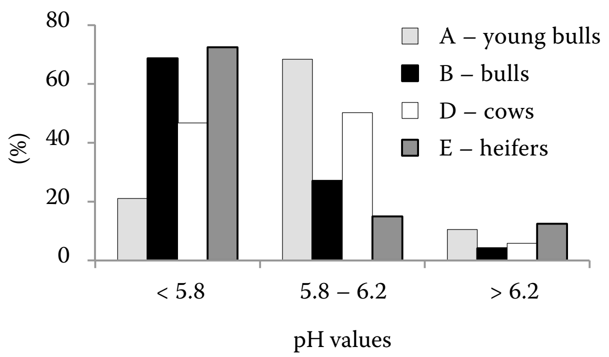

Figure 2. Percentage distribution of pH values in meat of different categories of cattle slaughtered in the winter season

(A, B, D, E) cattle categories according to EUROP system

categories the frequency of meat with proper pH was lower and amounted to 12.0%, 11.5% and 32.0%, respectively, in young bulls, bulls and cows. In the summer season defective DFD meat (pH > 6.2) was found in as much as 29% of young bulls, more than 11% of bulls, 5.8% of cows and 1.3% of heifers. On the other hand, the frequency of DFD meat occurrence was lower in winter, and depending on the cattle category it ranged from 5 to 12%. The results of many hitherto investigations indicate the lowest frequency of dark-cutting beef in steers and heifers, slightly higher in cows and the highest in young bulls. A high share of meat classified as DFD in the hot season was reported by Kadim et al. (2004) and Mitlöhner et al. (2002). Kadim et al. (2004) reported that 59% of LT muscles collected during the hot season had ultimate pH values higher than 6.0. Similarly, Kreikemeier et al. (1998) found that the highest numbers of dark-cutters occurred in carcasses of cattle that were harvested in summer heat. The studies carried out by Fabiansson et al. (1984) revealed that pH of LM was lower when the temperature during transport was also lower (R^2 = 7.99%). They supposed that when the temperature was above 18°C, the transport was physically demanding for the bulls.

CONCLUSIONS

In conclusion it should be stated that the season of slaughter significantly affected meat pH and all colour parameters. Meat obtained in the winter season was characterized by brighter red colour and higher values of a^*, b^*, C^* and h^* parameters in comparison with meat produced in summer. In the summer season a higher frequency of meat with improper values of pH > 5.8 was observed. Almost 30% of meat from young bulls slaughtered in the summer season had high pH values of 6.2, which indicated DFD defect.

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