Potravinarstvo Slovak Journal of Food Sciences

Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 14, 2020, p. 135-141
https://doi.org/10.5219/1334
Received: 10 February 2020. Accepted: 11 March 2020.
Available online: 28 March 2020 at www.potravinarstvo.com

ISSN 1337-0960 (online)

COMPARISON OF THE PHYSICO-CHEMICAL MEAT QUALITY OF THE BREEDS MANGALITSA AND LARGE WHITE WITH REGARD TO THE SLAUGHTER WEIGHT

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ABSTRACT
The aim of this study was to compare the quality of *musculus longissimus dorsi* in the breeds of Mangalitsa and Large White with regard to the slaughter weight. Large White (LW) breed and White Mangalitsa (Ma) breed were used in the experiment. The system of housing and feeding was the same in both of the monitored breeds. The pigs were fed with the same feeding mixture *ad libitum.* According to the slaughter weight, the pigs were divided into three groups: up to 100 kg, 101 – 110 kg and over 110 kg. The breed Ma had a significantly lower drip loss than the breed LW. Evaluating the color of the meat, the LW breed has showed significantly higher L* (lightness, white ±black) and lower a* (redness, red ± green) values than the Ma breed. Within the chemical meat composition, the Ma breed had a significantly higher water content in MLD compared to the LW breed. Generally, there were no major differences in the meat quality between the Mangalitsa and Large White breeds. Finally it can be concluded that the breed Mangalitsa showed more favorable values of the physico-chemical indicators. Comparing the quality of the meat with regard to the slaughter weight, there were no large differences between individual weight groups. A higher slaughter weight has positively influenced mainly the color of the meat, as pigs weighing more than 110 kg achieved a significantly lower value of L* and a higher value of a* in comparison to pigs of the lower weight. As a positive effect of a higher slaughter weight can be considered its effect on the protein content in the meat, as pigs weighing over 100 kg have a significantly higher protein content in the meat than pigs weighing below 100 kg.

Keywords: Large White; Mangalitsa; pork quality; slaughter weight

INTRODUCTION
Pork quality has become a primary focus for producers, researchers, packers, processors, retailers, and ultimately, consumers **(Newcom et al., 2004)**. In the last few years, consumers and the meat industry have emphasized the descending quality of the pig meat offered, such as a high frequency of pale, soft and exudative (PSE) fault expressed by a high drip loss and low water-holding capacity, unacceptable taste of pork, and a low content of the intramuscular fat **(Florowski et al., 2006)**. The meat quality is evaluated according to the quality parameters, such as the pH, color, or the intramuscular fat content. Meat color is one of the main quality properties, which influences consumer's acceptance, but also reflects the quality of meat **(Alonso et al., 2009)**. Moreover, the meat classification based on the pH and color directly in the cutting plant could help to separate the low-quality meat (**Bednářová et al. 2014**). There are many factors that influence the final quality of meat, e.g. animal nutrition, transportation, handling and stunning, but it is well-known that the breed itself can affect the pork quality **(Gil et al., 2008; Pascual et al., 2007; Šimek et al., 2004)**.

Meat and the meat products from the autochthonous pigs are highly appreciated by consumers because of their high sensory quality **(Živković et al., 2012)**. A high amount of the intramuscular fat, great concentrations of the heme pigments and high levels of unsaturated fatty acids have been highlighted as some of the most relevant quality aspects in the muscles of the autochthonous pig breeds **(Stanišić et al., 2015)**.

The slaughter weight is considered an important factor determining the economic profitability of the pork production. Some disadvantages caused by the increased slaughter weight are related to the reduced pig performance, feed conversion efficiency, and excessive fat thickness **(Serrano et al., 2008)**. From the point of view of the meat quality, the slaughter weight has shown some effects on the meat color, since the darker and redder colors were found in the pork meat at increasing the slaughter weight **(Ellis et al., 1996; Latorre et al., 2004)**.

Additionally, the intramuscular fat content was found to increase with the increased slaughter weight from 100 to 130 kg **(Weatherup et al., 1998)**. However, the slaughter weight has not shown any effects on the total protein, salt-soluble protein, and instrumental colors or marbling scores **(Serrano et al., 2008; Sutton et al., 1997)**.

Considering the fact that quality of pork may be significantly influenced by a genotype, but also by the weight at slaughter, the aim of this study was to evaluate the physico-chemical parameters of pork of the Mangalitsa and Large White breeds with regard to the slaughter weight.

Scientific hypothesis

We have assumed that the Mangalitsa breed meat will have better physico - chemical parameters compared to the Large White breed and that a higher slaughter weight will have a positive impact on the meat quality indicators.

MATERIAL AND METHODOLOGY

Biological material

In the experiment, a total of 20 pigs were analysed, 12 pigs of the breed Large White (LW) and 8 pigs of the breed White Mangalitsa (Ma). The pigs were bred on the pig farm in the village of Žirany (Slovakia).

Feeding and rearing conditions

The housing and feeding systems were the same for both breeds. The pigs were bred under the intensive breeding conditions, while they were housed in groups so as to comply with the requirements for the minimum housing area according to Government Regulation (SR) no. 735/2002 Coll., laying down the minimum standards for the protection of pigs **(NCSR, 2002)**. There was a concrete floor in the pens, covered with the wheat straw. The temperature in the stables was kept at 18 – 20 °C. The air exchange in the stables was realized by a vacuum ventilation system. Water and feed intake in both breeds was *ad libitum.* Feeding of the pigs was provided by the automatic feeders designed for a dry compound feed, which was granulated in order to reduce dustiness. Nipple drinkers were used for watering. The nutritional composition of the used commercial feed mixture was as follows: crude protein 164.63 $g.kg^{-1}$, crude fat 36.25 $g.kg^{-1}$, crude fiber 48.89 $g.kg^{-1}$, ash 39.69 $g.kg^{-1}$, nitrogen free extract 710.53 $g.kg^{-1}$, metabolisable energy 13.10 $MJ.kg^{-1}$ (the data represent the proportion of individual components in the dry matter of the analyzed feed).

Sampling

After reaching the slaughter weight, the pigs were transported to the Experimental Center of Livestock at the Department of Animal Husbandry of the Slovak University of Agriculture in Nitra, where they were killed and subsequently analyzed. The slaughter was realized according to Government Regulation (SR) no. 432/2012 of the Coll. Of the Slovak Republic, establishing the protection of animals during the slaughter **(NCSR, 2012)**. The meat quality parameters were evaluated in the longest back muscle MLD (*musculus longissimus dorsi*) at the level of the last thoracic vertebra in the right carcass half.

Analysis of the physical indicators

The values of pH 45 minutes (pH_{45}) and 24 hours (pH_{24}) *post mortem* were measured by the pH meter HI99161 (Hanna Instruments, Romania) in the units $-\log_{10}[H^+]$. The electric conductivity was determined 45 minutes (EC_{45}) and 24 hours (EC_{24}) *post mortem* by using the instrument Quality Meter (Tecpro, Germany) in the unit $mS.cm^{-1}$. The drip losses in MLT were measured from 24 to 48 h *post mortem* by the method according to **Honikel (1998)**. The meat color was measured in MLD 24 hours *post mortem* by using the spectrophotometer CM-2600d with the CIE Lab space and illuminate D65 (Konica Minolta, Japan). **Commission Internationale de l'Eclairage (1975)** determined the following color coordinates: L* (lightness, white ± black), a* (redness, red ± green) and b* (yellowness, yellow ± blue). The values were recorded from the average of three random readings across the muscle surface.

Analysis of the chemical indicators

The basic chemical parameters were determined from a homogenized muscle sample *musculus longissimus dorsi* by the FT IR method (FourierTransform InfraRed) using the Nicolet 6700 device (Thermo Scientific, USA). The content of water (%), protein (%), intramuscular fat - IMF (%) and cholesterol ($mg.100g^{-1}$) were determined in the meat sample.

Statistical analysis

Statistical analysis of the obtained results was performed in the **IBM (2011)** SPSS Statistics 20 Program (IBM corp., New York). The Univariate Analysis of Variance (UNIANOVA) was used to assess the effect of genotype and the slaughter weight on the monitored meat quality parameters, with testing the contrasts by means of the Scheffe test at the level of significance p <0.05. The analysis was performed according to the following model equation:

$$Y_{ijk} = \mu + B_i + SW_j + e_{ijk}$$

where Y_{ijk} is an indicator of the meat quality, μ is the overall mean, B_i is the fixed effect (n = 2; Mangalitsa, Large White), SW_j is the fixed effect slaughter weight (n = 3; SW up to 100 kg, SW from 101 to 110 kg, SW over 110 kg), e_{ijk} is the random error. The Pearson correlation coefficient was used to calculate the correlation dependencies between the selected monitored indicators.

RESULTS AND DISCUSSION

Comparison of the physical meat quality indicators in MLD of the slaughtered pigs is shown in the Table 1. Analysis of the physical indicators has shown that the breed and the live weight have any effect on pH_{45}, pH_{24}, EC_{45}, EC_{24}, and the color range b*. Mangalitsa achieved higher pH_{45} values (6.26 ±0.20) compared to Large White (6.12 ±0.22). Similarly, **Lípová et al. (2019)** and **Tomović et al. (2016)** found out that Mangalitsa achieved higher pH_{45} values than its crossbreeds and the Large White breed. The highest pH_{45} values were reached by the pigs with a live weight over 110 kg (6.32 ±0.32).

Table 1 Comparison of the physical meat quality indicators *m. longissimus dorsi.*

Parameter	Breed (B)		Slaughter weight (SW)			Significance		
	Ma (n = 12)	LW (n = 8)	to 100 kg (n = 4)	101 – 110 kg (n = 12)	over 110 kg (n = 4)	B	SW	R^2
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*			
pH_{45}	6.26 ±0.20	6.12 ±0.22	6.21 ±0.10	6.17 ±0.21	6.32 ±0.32	n.s.	n.s.	0.15
pH_{24}	5.63 ±0.07	5.69 ±0.12	5.61 ±0.03	5.68 ±0.11	5.63 ±0.04	n.s.	n.s.	0.13
EC_{45}	3.50 ±0.34	3.38 ±0.32	3.45 ±0.40	3.42 ±0.36	3.55 ±0.17	n.s.	n.s.	0.05
EC_{24}	11.32 ±3.10	11.08 ±5.07	12.00 ±3.23	11.98 ±4.26	8.15 ±1.56	n.s.	n.s.	0.23
Drip loss	7.57 ±0.88	10.13 ±2.72	7.89 ±0.14	9.15 ±2.73	7.64 ±0.19	*	n.s.	0.35
CIE L*	51.71 ±2.84	58.75 ±1.85	54.85 ±2.16^b	56.03 ±4.40^b	49.68 ±0.82^a	***	**	0.85
CIE a*	3.52 ±1.96	0.59 ±0.65	1.32 ±0.29^a	1.68 ±1.90^a	5.38 ±0.08^b	***	***	0.87
CIE b*	10.79 ±1.22	10.44 ±0.42	10.43 ±0.79	10.48 ±1.11	11.38 ±0.28	n.s.	n.s.	0.15

Note: Ma: Mangalitsa, LW: Large White, n.s.: not significant, *: p <0.05, **: p <0.01, ***: p <0.001, different letters in the same row indicate significant differences among the mean values (p <0.05), R^2: coefficient of determination.

24 hours after slaughter, the pH_{24} values dropped to 5.63 ±0.07 in Mangalitsa and to 5.69 ±0.12 in Large White.
Similar pH_{24} values were found in MLD in the breed Ma (5.69 ±0.07) and in the hybrids of Ma x LW (5.68 ±0.11) by **Lípová et al. (2019)**. **Alonso et al. (2009)** found the pH_{24} values of various commercial hybrids at the level of 5.70 - 5.74. Contrary to these findings, **Stanišić et al. (2015)** found higher MLD muscle acidification 24 hours *post mortem* in Mangalitsa at the level of 5.47 ±0.07 and in Landrace at the level of 5.47 ±0.10. In accordance with the results of our study, **Ba et al. (2019)** did not detect any significant differences in pH_{24} values in relation to the pig weight.

Electric conductivity, 45 minutes after slaughter (EC_{45}), was recorded in the breed Ma (3.50 ±0.34 $mS.cm^{-1}$) and LW (3.38 ±0.32 $mS.cm^{-1}$). After 24 hours, there was a significant increase in the electric conductivity (EC_{24}) to 11.32 ±3.10 $mS.cm^{-1}$ for Ma and 11.08 ±5.07 $mS.cm^{-1}$ for LW. Lower EC_{24} values in the breed Ma (9.31 ±1.91 $mS.cm^{-1}$) and the crossbreeds Ma x LW (10.86 ±2.25 $mS.cm^{-1}$) were found by **Lípová et al. (2019)**. In the commercial hybrids, **Mörlein et al. (2007)** found in the study the value EC_{24} at the level 6.24 ±2.32 $mS.cm^{-1}$. In assessing the meat quality deviations, the EC_{24} values at the level of 7 $mS.cm^{-1}$ and 9 $mS.cm^{-1}$, respectively, were used as the criterion for the PSE meat (pale, soft, exudative). It follows from the above that some individuals of both monitored breeds have shown deteriorated meat quality in this indicator. In terms of comparing pigs by their live weight, the EC_{24} values were decreasing with the weight gain.

In the drip loss indicator, the Ma breed (7.57 ±0.88%) had a significantly lower drip loss (p <0.05) than the LW breed (10.13 ±2.72%). No significant differences were found within the weight groups and the confidence of estimation was 35% (R^2 = 0.35). **Lípová et al. (2019)** found similar drip loss values for the Ma breed (7.15 ±2.99%) and the higher ones for the Ma x LW hybrid (8.22 ±2.78%). **Mörlein et al. (2007)** and **Fischer et al. (2000)** found out that the smallest drip loss was reported by the crossbreeds that contained the breed Duroc.

Color is considered an important indicator of the pork quality, as it is one of the most important characteristics affecting consumers´ ratings of meat **(Valous et al., 2010)**. The analysis of the L* values has shown that both the breed (p <0.001) and the live weight (p <0.01) had a significant effect on the meat lightness, with a confidence estimate of 85 (R^2 = 0.85). The LW breed had a lot lighter meat than the Ma breed (58.75 ±1.85 vs. 51.71 ±2.84) and the pigs weighing over 110 kg had significantly darker meat than the lower weight pigs (p <0.05). The a* indicator, representing the meat redness, has also shown a significant effect of the breed (p <0.001) and the live weight (p <0.001), the reliability of the estimate was at 87% (R^2 = 0.87). Meat of the Ma breed was redder compared to the LW breed (3.52 ±1.96 vs. 0.59 ±0.65) and the pigs weighing over 110 kg had significantly redder meat compared to the lower weight pig groups (p <0.05). Neither the breed nor live weight had a significant effect on the indicator b*, which represents the yellowness of the meat. Several authors have found out, when comparing the meat color of the Ma breed with other breeds, respectively with the hybrids of the mangalitsa breed, that the meat of the Ma breed is darker and redder, which is in accordance with our results **(Lípová et al., 2019; Tomović et al., 2016; Tomović et al., 2014)**. **Ba et al. (2019)** comparing the meat color depending on the slaughter weight of the pigs found any significant differences in the meat lightness (L*). In the a* and b* indicators pigs with a higher slaughter weight (120 kg) had significantly redder and yellower meat than the pigs weighing 100 kg. Similarly, **Latorre et al. (2004)** found a higher a* value in MLD of the pigs killed at a higher weight (132 kg) compared to the pigs that were killed at a lower weight (116 kg). Contrary to our results, **Correa et al. (2006)** and **Serrano et al. (2008)** found no significant differences in the meat color depending on the weight of the slaughter pigs.

The basic chemical composition and cholesterol content are shown in the Table 2. The Ma breed had a significantly higher water content in MLD (p <0.05) compared to the LW breed (70.42 ±0.41% vs. 69.22 ±1.51%). However, the slaughter weight have any effect on this indicator and the reliability of the estimate was at the level of 31% (R^2 = 0.31). In contrast, the genotype (n.s.) have any influence on the the protein content of MLD, but the slaughter weight (p <0.05), with a confidence estimate of 53% (R^2 = 0.53). Pigs weighing up to 100 kg had a significantly lower protein content in meat (24.32 ±0.01%) than the pigs of higher weight. The weight categories 101 – 110 kg and over 110 kg had similar

Table 2 Basic chemical composition of the meat and cholesterol content in *m. longissimus dorsi*.

Parameter	Breed (B)		Slaughter weight (SW)			Significance		
	Ma (n = 12)	LW (n = 8)	to 100 kg (n = 4)	101 – 110 kg (n = 12)	over 110 kg (n = 4)	B	SW	R^2
	Mean ± SD	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*	*Mean ± SD*			
Water	70.42 ±0.41	69.22 ±1.51	70.23 ±0.59	69.72 ±1.42	70.29 ±0.18	*	n.s.	0.31
Protein	24.64 ±0.35	25.02 ±0.27	24.32 ±0.01[a]	24.92 ±0.31[b]	24.87 ±0.37[b]	n.s.	*	0.53
IMF	1.34 ±0.38	0.98 ±0.24	1.56 ±0.20	1.07 ±0.40	1.22 ±0.03	n.s.	n.s.	0.35
Cholesterol	44.17 ±5.77	40.00 ±2.14	47.50 ±0.58	40.50 ±5.45	43.50 ±0.58	n.s.	n.s.	0.33

Note: Ma: Mangalitsa, LW: Large White, IMT: intramuscular fat, n.s.: not significant, *: p <0.05, different letters in the same row indicate significant differences among the mean values (p <0.05), R^2: coefficient of determination.

protein content in MLD (24.92 ±0.31% and 24.87 ±0.37%).

The opposite tendency of the slaughter weight influence on the protein content was found by **Ba et al. (2019)** and **Raj et al. (2010)**, who recorded a significantly lower protein content in the pigs of the greater weight (110 – 130 kg) than in the pigs of the lower weight (90 – 110 kg). The differences between breeds were not conclusive (Ma: 24.64 ±0.35%, LW: 25.02 ±0.27%). **Parunović et al. (2013)** found a higher proportion of water in MLD of the Swedish Landrace (72.70%, p <0.001) than in the Swallow-bellied Mangalitsa breeds 64.30% and the White mangalitsa 62.70%, while the difference in water content among the mangalitsa breeds was not significant. **Kim et al. (2016)** found the water content in MLD for the Berkshire breed at the level of 75%. **Holló et al. (2003)** found that different slaughter weight had no effect on the water content of the MLD muscle of the Mangalitsa breed. The water content was 68.80 ±2.01% in the pigs weighing 91.64 ±2.41 kg and 68.96 ±2.60%, in those with the weight of 114.14 ±7.70 kg, which is comparable to our results.

Regarding the protein content in MLD, the differences between the breeds were not significant (Ma: 24.64 ±0.35%, LW: 25.02 ±0.27%). Contrary to our results, several authors found a lower protein content in the Mangalitsa breed, ranging from 19.50% to 21.83% **(Tomović et al., 2016; Stanišić et al., 2015; Parunović et al. 2013; Holló et al., 2003)**. Vice versa, **Lípová et al. (2019)** found a similar protein content in Mangalitsa (24.15 ±0.66%). Also, in the meat breeds and crossbreeds, there are not clear results of protein content in MLD. **Tomović et al. (2016)** found a protein content of 21.82 ± 0.12% in the Large White breed, **Parunović et al. (2013)** in the Swedish Landrace 22.10%, **Ruusunen et al. (2012)** in various breeds in Scandinavia 21.8 to 22.9%, **Kameník, Saláková and Kašpar (2018)** in the Danish-Norwegian breed Topigs 24.40%, **Stanišić et al. (2015)** in Landrace 23.43 ±1.71%.

An important indicator which affects the taste properties of meat is the content of the intramuscular fat (IMF). According to **Fortin, Robertson and Tong (2005)**, the optimal IMF content in meat is 1.5 to 2.5%. The Ma breed had a higher IMF content (1.34 ±0.38%) compared to the LW breed (0.98 ±0.24%), but this difference was not statistically significant. Similarly, no significant differences were observed among groups with different slaughter weights. The IMF content was relatively low in both breeds compared to other authors, e.g. as far as the Ma breed is concerned**, Ender et al. (2002)** found the IMF content 9.00%, **Holló et al. (2003)** 8.38%, **Stanišić et al. (2015)** 6.40%. **Matoušek et al. (2016)** and **Nevrkla et al. (2017)** found the IMF content of the Czech autochthonous breed Prestice Black-pied pig at the level of 2.47% up to 2.89%. **Tomović et al. (2016)** found the IMF content at the level of 2.56% in the Large White breed.

Neither the breed nor the different slaughter weight had any effect on the cholesterol content in MLD. However, the Ma breed had by 4 $mg.100g^{-1}$ of cholesterol in the meat more than the LW breed (44.17 ±5.77 $mg.100g^{-1}$ vs.

Table 3 Correlation coefficients of the physico-chemical indicators *m. longissimus dorsi* in relation to slaughter weight and the IMF content.

	Slaughter weight	IMF
pH_1	0.304	0.086
pH_2	- 0.008	- 0.031
EC_1	0.160	- 0.038
EC_2	- 0.265	0.416
Drip loss	- 0.104	- 0.283
CIE L*	- 0.449*	- 0.282
CIE a*	0.598**	- 0.061
CIE b*	0.222	- 0.481*
Water	0.054	0.524*
Protein	0.356	- 0.506*
IMF	- 0.164	1
Cholesterol	- 0.159	0.813**

Note: IMT: intramuscular fat, *: p <0.05, **: p <0.01.

40.00 ±2.14 mg.100g^{-1}). Comparable values of the cholesterol content in MLD were also found by **Lípová et al. (2019)** in the Ma breed (43.01 mg.100g^{-1}) and the hybrids Ma x LW (38.91 mg.100g^{-1}).

Pârvu et al. (2012) have reported a similar cholesterol content in the Ma breed (41.64 mg.100g^{-1}), but they had a significantly higher cholesterol content of 61.24 mg.100g^{-1} in the LW breed. In contrast to our findings, other authors have reported higher cholesterol levels in MLD in the Ma breed, ranging from 61.14 to 62.90 mg.100g^{-1} **(Parunović et al., 2013; Petrović et al., 2010)**.

Table 3 shows the correlation coefficients of the physico-chemical indicators in relation to slaughter weight and the IMF content. The slaughter weight positively correlated with the indicator a* (p <0.01, r = 0.598) and negatively with the indicator L* (p <0.05, r = -0.449). It follows from the above that the pig meat is darker and redder with the increase of the slaughter weight. **Ba et al. (2019)** have stated that increase of the slaughter weight is associated with the redder and yellower meat. In terms of the physico-chemical indicators, the IMF content correlated negatively with the indicator b* (p <0.05, r = -0.481). In contrast, **Ba et al. (2019)** found a positive relationship between the value b* and the fat content (r = 0.652, p <0.05). Within the chemical meat composition, the IMF content correlated positively with water (p <0.05, r = 0.524) and cholesterol (p <0.01, r = 0.813) and negatively with the protein content (p <0.05, r = -0.506). Contrary to our results, several authors have found a negative relationship between the IMF content and water in the MLD muscle **(Tomović et al., 2014; Vranic et al., 2015; Lípová et al., 2019)**.

CONCLUSION

There were no major differences in the meat quality between the Mangalitsa and Large White breeds. Nevertheless, we can conclude that the breed Mangalitsa has showed more favorable values of the physico-chemical indicators, as it has achieved a significantly lower drip loss (7.57% vs. 10.13%, p <0.05), a lower value of L* (51.71 vs. 58.75, p <0.001) and a higher value of a* (3.52 vs. 0.59, p <0.001). That means that meat of the Mangalitsa breed had a better water holding capacity, was darker and redder in comparison to the Large White breed. Similarly, when comparing the quality of the meat with regard to the slaughter weight, there were no large differences between individual weight groups. However, a higher slaughter weight has positively influenced mainly the color of the meat, as pigs weighing more than 110 kg achieved a significantly lower value of L* (p <0.01) and a higher value of a* (p <0.001) in comparison to pigs of the lower weight. As a positive effect of a higher slaughter weight its effect on the protein content in the meat can be considered, as pigs weighing over 100 kg had a significantly higher protein content in the meat than pigs weighing below 100 kg (p <0.05).

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Acknowledgments:

This work was supported by grant KEGA No. 039SPU-4/2019.

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