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Original Scientific Paper

Effect of marbling on pork nutritional value

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ABSTRACT

In the context of the dilemma between tasty and healthy food, obtaining and analyzing information on the nutrients composition of commercial marbled pork make significant interest from the point of view of the right choice of a long-term strategy for the pork producers. This study considers the influence of marbling degree of commercial pork on the nutritional parameters, fatty acid composition, content of selenium, zinc, iron, copper, and vitamins, B1, B2, B5, B6, B12, B3, and D3. It was shown that a high degree of marbling affects only the energy value, producing no effect on the protein content in the meat. The increase of fat content depending on the pork marbling degree was noted, and a correlation between the degree of marbling and the ratio of omega-3:omega-6 fatty acids was found, which proves the high biological value of marbled meat and allows consideration of its possible use in manufacturing functional food products. Analysis of the vitamin and mineral composition of the marbled meat showed that the degree of pork marbling does not affect their quantitative content in the meat.

1. Introduction

Nowadays, pork is the second most commonly consumed meat all over the world (*OECD-FAO Agricultural Outlook*, 2021). In the future, the level of pork consumption will depend on the degree to which the consumers' expectations are met, and it may change over time with the emergence of new trends in human nutrition, social and economic considerations as well as social and cultural factors (*Chernukha et al*., 2023; *Vitale et al*., 2020). In this regard, large-scale pork producers (agricultural holdings) are interested in the correct choice of long-term strategies to increase the market competitiveness of pork, and thus, maintain a high level of its consumption in various countries.

It is known that marbling significantly improves such sensory characteristics of meat as juiciness, tenderness, aroma, taste perception, so pork marbling can be attractive for consumers (*Simunović et al*., 2024). Accordingly, the production of marbled pork can provide certain market competitive advantages for the pork producers. However, pork marbling is associated with an increased content of intramuscular fat, including visible fat. With the rapidly growing desire in society for healthy eating, plus the global trends for reducing fat consumption and the overall caloric content of the diet, the long-term trend for marbled pork consumption is now in doubt. Meat marbling can lead to a deterioration of the pork nutrient profile, and, accordingly, consumers can refuse to buy such meat, instead favouring

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less fatty meats, including those recommended by nutritionists.

In Russia, according to official statistics, in recent years the number of pigs and their commercial husbandry have grown significantly, which has led to the country's complete self-sufficiency in pork meat supply, with no imported pork. On the contrary, in recent years, agricultural holdings have been actively increasing pork exports, considering new strategies for expanding the range of pork and satisfying consumer demand in the domestic and foreign markets (*Kovalev*, 2023). In the context of the dilemma between tasty and healthy food, obtaining and analyzing information on the nutrient composition of commercial marbled pork makes sense in terms of choosing the right long-term strategy for the pork producers.

The purpose of the work was to study selected nutritional parameters, i.e., fatty acid composition, selenium, zinc, iron, and copper content, and vitamins, B1, B2, B5, B6, B12, B3, and D3, depending on the degree of marbling of the commercial pork.

2. Materials and methods

The studied meat was musculus L. dorsi with varying degrees of marbling, samples of which were obtained from pigs aged 185-195 days as a result of slaughter at an commercial enterprise (AGROEKO-YUG LLC) located in Voronezh region of the Russian Federation.

Twenty-four hours after slaughter, the chilled pork carcasses were selected by the company's employees, who were specially trained to assess the degree of marbling using a visual scale of five marbling categories. Three categories were selected, i.e., the maximum, the medium and the minimum levels of marbling. The back-rib cut excised from the selected carcasses, deboned and vacuum-packed. Cuts were then delivered to the laboratory for testing.

To ensure greater variability in the composition of the meat cuts, those with the maximum degree of marbling (group 1) were taken from the carcasses obtained by slaughtering a herd of Duroc pigs that had been fed with additional carbohydrate nutrition for 51 days. The rest of the meat cuts were selected from the carcasses obtained by slaughtering hybrid pigs that were fed with a standard diet; these hybrids were typically used in the commercial production of pork at the enterprise. The cuts obtained from the hybrid pigs were visually classified by the degree of marbling as having the medium degree of marbling (group 2) or the minimum degree of marbling (group 3).

Thus, each group of meat cuts comprised three samples of m. L. dorsi, categorized into the relevant group according to the degree of marbling (9 samples, in total).

From the middle part of m. L. dorsi, three 2 cm thick steaks were cut out, their cross-sections were photographed and the steaks were used to prepare an average sample sent for the chemical analysis.

To objectively assess the marbling, the photographs of the steak were processed using an image analyzer. The amount of visible intramuscular fat was determined in the software ImageJ (https://imagej.net/download.html) using photographs of the "loin eye" (m. L. dorsi). The number of fat inclusion dots was calculated as a percentage of the area of the entire loin eye.

The nutritional value parameters were determined using standard methods accepted in Russia and relevant to general laboratory practice: mass fraction of protein was determined according to *GOST 25011* (2017); mass fraction of fat – according to *GOST 23042* (2015); fatty acid composition – according to *GOST 31663* (2012); mass fraction of zinc, copper according to *GOST 30178* (1996); mass fraction of selenium – according to *GOST 31707* (2012); mass fraction of vitamins – according to *GOST 323072* (2013), *GOST R 55482* (2013).

The analyses were repeated three times. The data were processed by analysis of variance (variation statistics) using the Microsoft Excel 2010 software, as well as using the Statistica 10.0 software. The results were compared using one-way analysis of variance (ANOVA) and the Tukey-Kramer test. The differences were considered reliable and the correlation between the parameters was considered, when the probability level did not exceed 0.05.

3. Results and discussion

The amount of visible intramuscular fat in the different groups of m. L. dorsi was rated in the laboratory environment with the help of an image analyzer (Table 1).

The content of the visible intramuscular fat differed significantly between the groups ($p<0.05$), which generally proved the correctness of the sample selection by the company's specialists. Meanwhile, the cuts with the maximum degree of marbling (group 1) exceeded the degree of marbling in

groups 2 and 3 by 2.5 and 4.9 times, respectively, i.e., the ratio of marbling in groups 1, 2, and 3 was 1.0:0.4:0.2. This supports the conclusion that in the future it should be possible to improve the marbling assessment and increase its objectivity by switching to an instrumental assessment method.

Table 1. Visible intramuscular fat content in m. L. dorsi

Parameter	Groups of meat cuts selected according to the degree of marbling		
	Group 1	Group 2	Group 3
Representative photo of the loin eye (m. L. dorsi)			
Content of the visible intramuscular fat (%, mean ± SEM)	13.56±1.19	5.52±0.5	2.79±0.94

The study of the main parameters of the cuts' nutritional value (Figure 1) showed that all three groups featured a high level of protein, and there were no statistically significant differences in this parameter. At the same time, in terms of fat content, the marbling groups differed reliably ($p<0.05$). In terms of fat content, the ratio of groups 1, 2 and 3 was 1.0:0.6:0.5. This means the difference in total fat between the groups was less than in visible fat, although in general the values of these parameters correlated.

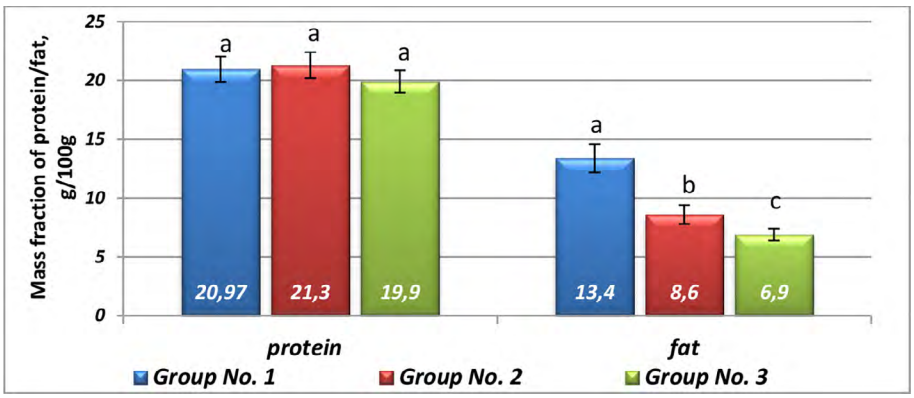

Figure 1. Protein and fat content in m. L. dorsi depending on the marbling degree. *a, b, c - values without a common superscript letter differ ($p < 0.05$).*

The energy value (caloric content) of the cuts with different degrees of marbling also showed significant differences. Thus, the caloric content of the samples from group 1 was 204.5±19.7 kcal, group 2 – 162.6±11.6 kcal and group 3 – 141.7±8.3 kcal. Meanwhile the difference in caloric ratios between the groups was even less than for the total fat content (1.0:0.8:0.7).

Thus, pork with the highest degree of marbling, due to its higher fat content, featured the highest energy value. However, an increase in marbling did not cause proportional changes in the fat content and caloric value. At the same time, a high degree of marbling did not affect the protein content of the meat.

Analysis of effect on the marbling degree on the fatty acid composition in the meat cuts (Table 2) showed that the samples of group 3 with the least degree of marbling had the lowest values of polyunsaturated fatty acid content, including the omega-3 and omega-6 acids families.

In terms of the content and ratio of saturated, monounsaturated and polyunsaturated fatty acids, which characterize the balance of the fatty acid composition from the point of view of healthy nutrition (*Briggs et al*., 2017), the best parameters were found in the meat cuts with the maximum and the medium degrees of marbling. The higher content of PUFA in these cuts was provided mainly by linoleic (omega-6)

and linolenic (omega-3) fatty acids. Meanwhile, in terms of the ratio of polyunsaturated fatty acid content, i.e., the ratio of the omega-3 to omega-6 acid families, only the group 1 cuts featured a positive difference—in contrast to the cuts in groups 2 and 3—and matched the standards of physiological needs of the human body established in Russia (*Methodological recommendations MR*, 2021). According to many researchers, a high PUFA content, including the omega-3 family, provides beneficial effects on consumers' health (*Therkildsen et al*., 2021; *Aboagye et al*., 2020).

Table 2. Fatty acid composition of m. L. dorsi depending on the degree of marbling

Parameter	Group 1	Group 2	Group 3
Myristic C14:00	1.40 ±0.37 [a]	-	-
Palmitic 16:0	24. 55 ±2.95 [a]	25.00±3.00 [a]	26.20±3.10 [a]
Palmitoleic C16:1	2.30 ±0.57 [a]	1.80±0.40 [ab]	1.50±0.40 [b]
Margaric C17:0	0.40 ±0.08 [a]	-	-
Heptadecenoic C17:1	0.40 ±0.09 [a]	-	-
Stearic C18:0	11.30 ±1.36 [a]	13.90 ±1.70 [b]	15.00 ±1.80 [b]
Oleic C18:1	39. 25 ±4.72 [a]	38.40 ±4.60 [a]	40.30 ±4.80 [a]
Linoleic C18:2ω6	16.60 ±1.99 [a]	17.30 ±2.10 [a]	13.90 ±1.70 [b]
Linolenic C18:3ω3	2.00 ±0.49 [a]	1.60 ±0.40 [a]	1.00 ±0.30 [b]
Arachidic C20:0	0.40 ±0.12 [a]	0.40 ±0.10 [a]	0.40 ±0.10 [a]
Eicosadienoic C20:2ω6	0.70 ±0.18 [a]	0.80 ±0.20 [a]	0.70 ±0.20 [a]
Gondoinic C20:1ω9	0.70 ±0.17 [a]	0.80 ±0.20 [ab]	1.00 ±0.20 [b]
∑SFA	38.0 5 ±4.88 [a]	39.30±4.80 [a]	41.60±5.00 [a]
∑ MUFA	42. 65 ±5.55 [a]	41.00±5.20 [a]	42.80±5.40 [a]
∑ PUFA	19.30±2.66 [a]	19.70±2.70 [a]	15.60±2.20 [b]
SFA:MUFA:PUFA	2.0:2.2:1	2.0:2.1:1	2.7:2.7:1
∑ ω3	2.00±0.49 [a]	1.60±0.40 [a]	1.00±0.30 [b]
∑ ω6	17.30±2.17 [a]	18.10±2.30 [a]	14.60±1.90 [b]
ω3: ω6	1.0:8.6	1.0:11.3	1.0:14.6

a, b - values in rows without common superscript letter differ ($p<0.05$).

It is necessary to note that the fatty acid composition also depends on the pig's fattening, the farming conditions, and genetic characteristics of the pig's breed, which can also have some effect on the pig's lipogenesis (*Yashin et al*., 2020). However, the effect of marbling on a higher content of monounsaturated and polyunsaturated fatty acids, including omega-6 and omega-3 groups, is also underlined in the other studies (*Joo et al*., 2017; *Shlykov*, 2016).

Despite the important role of meat in providing some vitamins and minerals, the studies on the effects of marbling have generally been limited to fatty acid composition. In this regard, the results on vitamin and mineral content (Table 3), obtained by us, are of additional interest.

As is visible from Table 3, the studies conducted did not reveal a correlation between the degree of marbling of pork muscle tissue and the quantitative content of vitamins and minerals in the meat. According to the data obtained, among the three groups, the greatest potential for healthy nutrition was found for the group 1 cuts that had the maximum degree of marbling, in which a high content (more than 30% of the daily requirement) of selenium and vitamins B6, B3 and D3 was noted. In the cuts of groups 2 and 3, a high content of selenium was noted, as well as vitamin B6 (group 2) and vitamin B3 (group 3), the content of which was possibly related to the additives in the diet of the Duroc variety pigs.

In modern literature databases, most research devoted to the analysis of trace elements accumulation in muscles have found no variations at the level of genetic manipulations. Thus, a study (*Tomović et al*., 2011) conducted in Serbia showed that the content of minerals in pork muscle tissue (m. Semimembranosus), obtained from two purebred pigs

Table 3. Content of vitamins and minerals in m. L. dorsi depending on the marbling degree

Parameter	Group 1	Group 2	Group 3
Selenium, mg	0.035±0.011 [a]	0.036±0.011 [a]	0.028±0.008 [b]
Zinc, mg	2.353±0.479 [a]	1.734±0.369 [b]	2,220±0,455 [a]
Iron, mg	0.989±0.375 [a]	0.705±0.336 [b]	0.750±0.342 [b]
Copper, mg	0.090±0.029 [a]	0.025±0.017 [b]	0.022±0.017 [b]
Vitamin B1, mg	0.15±0.03 [a]	0.14±0.03 [a]	0.10±0.02 [b]
Vitamin B2, mg	0.02±0.007 [a]	0.14±0.06 [b]	0.04±0.01 1 [c]
Vitamin B5, mg	0.50±0.10 [a]	0.66±0.15 [b]	0.47±0.09 [a]
Vitamin B6, mg	0.72±0.18 [a]	0.64±0.16 [a]	0.41±0.10 [b]
Vitamin B12, µg	LESS THAN 1.00	LESS THAN 1.00	LESS THAN 1.00
Vitamin B3, mg	17.00±3.40 [a]	5.33±1.07 [b]	16.40±3.28 [a]
Vitamin D3, µg	1.50±0.40 [a]	LESS THAN 1.00	LESS THAN 1.00

a, b, c - values in rows without common superscript letter differ ($p < 0.05$).

and eight crossbred pigs, did not depend on genetic lines. It was noted that the fortification of meat with selenium and copper can be achieved by regulating and enriching the feed for the pigs with these elements. It was also noted that the copper content in meat obtained from different pig breeds varied within the same range from 0.03 to 1.40 mg/100 g of product (*Kurbanova et al*., 2023).

4. Conclusion

Research into the effect of marbling on the nutritional value of m. L. dorsi of pigs did not reveal any statistically significant differences in the protein content in the analyzed cuts that had various degrees of marbling. An increase in fat content was noted directly depending on the degree of pork marbling, and a correlation was found between the degree of marbling and the ratio of omega-3:omega-6 fatty acids. In the meat cuts with the maximum degree of marbling, optimal values of this parameter were noted, and which correspond to the norms of physiological needs of the human body established in Russia (*Methodological recommendations MR*, 2021). The analysis of the vitamin and mineral composition of the meat cuts showed that the level of marbling of pork does not affect their quantitative content in the meat.

In general, the results obtained confirm the data on the high content of individual vitamins and minerals in pork. In addition, despite the increase in the quantitative content of fat depending on the meat marbling degree, its biological value also increases. The use of this marbled raw meat, including for the production of functional food and specialized nutrition, will provide not only appealing taste characteristics, but also will ensure high quality of the food products in terms of their nutritional and biological value. This will help in solving the issue of eliminating health problems associated with the consumption of fatty pork. Thus, the choice of a strategy for marbled pork consumption from the point of view of its assessed nutritional value should not be in conflict with the trend for healthy eating.

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