COMPARATIVE ASSESSMENT OF NUTRITIONAL AND BIOLOGICAL VALUE OF BEEF FROM CALVES OF VARIOUS BREEDS

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Abstract. The article presents the results of the research studies on comparative assessment of the nutritional and biological value of beef from calves of Simmental (I), Black-and-White (II), Bestuzhev (III), Hereford (IV) and Aberdeen Angus (V) breeds. The calves of Simmental, Hereford, and Aberdeen Angus breeds had the parameter of the carcass weight higher than the calves of Black-and-White and Bestuzhev breeds, at the average, by 7.3 (3.2 %) and 14.6 kg (6.7 %), respectively. The protein proportion in meat of the calf carcasses in all groups was 18.60-19.24 %. The meat from the Hereford youngsters contained more fat than meat of the calves in group I by 1.05 %, in group II – by 1.51 %, and in group III – by 1.77 %. The calculation of the biological value of protein showed that the beef breeds have a more balanced ratio of essential amino acids in their meat. The total content of amino acids in meat from the animals of the Aberdeen Angus breed was 327 mg per 1 g of protein, which is more by 3.8 %, 13.1, 11.2, and 2.8 % as compared with the calves in groups I, II, III, and IV. Thus, the beef obtained at slaughter of young stock of different breeds was evaluated as complete and balanced raw material in the matter of amino acid composition. Containing all essential amino acids for the protein synthesis flow, the meat was qualified for human consumption.

Keywords: carcass meat, biological value, culinary-technological properties, taste assessment, breed.

Introduction

Beef is essential for the formation, development, and functioning of the human body. It contains essential proteins, fats, minerals, vitamins, enzymes, and other ingredients (components) essential for human nutrition that are digested and absorbed for 95 %. Beef is an universal meat suitable for human consumption of any age [1]. The quality of meat depends on good nutrition, housing conditions, and the breed of the animals [2-4].

Beef is the main source of complete proteins in the human diet and contains all essential amino acids necessary for providing the plastic processes in the body. However, its nutritional and biological value depends on many factors. The animal breed should be considered to be one of them [5; 6]. In particular, the beef from the animals of specialized meat breeds have high taste, nutritional and cooking qualities. It is usually attributed to the most valuable food. This is due to the fact that these animals have a peculiar type of metabolism, which determines their high quality meat production [7].

In view of the above, the purpose of the present research was a comparative assessment of the nutritional and biological value of meat from the calves of different breeds under the conditions of industrial technology of beef production.

Materials and methods

The experimental part of the work was carried out at the industrial fattening complex of Open Joint-Stock Company (OJSC) n.a. N.E. Tokarlikov, the Republic of Tatarstan. Five groups of calves of different breeds and productivity trends were selected for the experiment: Simmental (group I), Black-and-White (group II), Bestuzhev (group III), Hereford (group IV), Aberdeen-Angus (group V), 18 heads in each. The calves in groups I, II, III aged from 1 to 14.5 months were kept in an industrial complex, and the calves of Hereford and Angus breeds were grown from birth to 6 months of age in a process of the beef cattle breeding according to the principle “cow-calf”. After weaning from their mothers, the calves were transferred to the complex and were kept there up to their 14.5 months of age.

Feeding and housing the experimental animals was carried out in accordance with the program adopted by the fattening industrial complex and the rations were balanced according to the detailed feeding standards [8].

The control slaughter of animals was performed to study the beef production. The chemical composition of the carcass flesh and the eye muscle of loin was examined in accordance with the

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guidelines. The content of complete and imperfect proteins as well as of essential amino acids was established using the capillary electrophoresis Kapel®-105M (“Lumex”, Russia). The data obtained were compared to the reference protein standard of the World Health Organization/Food and Agriculture Organization (WHO/FAO, 2007). The fatty acid content of intramuscular fat was determined by the liquid-chromatograph LC®-10 (“Shimadzu”, Japan) with a fluorometric detector and precolumn derivatization according to the manufacturer’s recommendations.

The data on different variables, obtained from the experiment, were statistically analyzed by Statistica 10 package (StatSoft Inc.). The significance of differences between the indices was determined using the criteria of nonparametric statistics for the linked populations (differences with $p < 0.05$ were considered significant: ***$p < 0.001$; ** $p < 0.01$; * $p < 0.05$; ns (not significant) at $p > 0.05$). Student’s t-test and Wilcoxon test were applied for the statistical analysis. Regression and correlation analyses were also computed to establish relationships among various parameters [9].

The protein quality indicator (PQI) was calculated using the following formula (1):

$$PQI = \frac{\text{Tryptophane}}{\text{Oxyproline}}. \tag{1}$$

The water retention capacity (WRC) was determined by the classical method of Grau & Hamm [10].

The thermal weight loss (TWL) was expressed as a percentage of the difference between initial weight and after cooking of samples.

The culinary-technological properties (CTP) of meat were expressed by the ratio of the storage capacity of the water (WRC) to heat weight loss (TWL).

The amino-acid score (AAS) was calculated as follows [11]:

$$AAS,\% = \frac{\text{Evaluated protein amino acid content (g per 100g protein)}}{\text{FAO scoring model amino acid content (g per 100g protein)}} \cdot 100. \tag{2}$$

The coefficient of amino-acid score difference (CAAS) was estimated in accordance with Nikitina et al. [12] by the following formula (3):

$$CAAS,\% = \frac{\sum (C_i - C_{\min})}{\text{n}}, \tag{3}$$

where C_i – is the excess of amino-acid score, %;
$C_{\min}$ – is the minimum score of essential amino acids of evaluated protein relative to the physiological norm (FAO scoring model amino acid content), %;
n – is the number of essential amino acids.

The biological value (BV) was calculated by the following formula (4):

$$BV,\% = 100 - CAAS. \tag{4}$$

The nutritional value (NV) was estimated in accordance with the following formula (5):

$$NV, kcal/1kg = (4 \cdot P + 9 \cdot F + 4 \cdot C) \cdot 4.2 \cdot 10 \cdot 0.001, \tag{5}$$

where P – is the percentage of protein, %;
F – is the percentage of fat, %;
C – is the percentage of carbohydrates, %;
4.2 – is the conversion factor of 1 kcal into 1 kJ;
10 – is the conversion factor of 100 g into 1 kg;
0.001 – is the conversion factor of 1 kJ into 1 MJ.

MS Office 2010 package was employed for graphical presentation of the data.

The experiments were performed in accordance with the Guide for the care and use of laboratory animals [13].

Results and discussion

The control slaughter of the test animals aged 14.5 months showed that the calves of Simmental, Hereford, and Aberdeen Angus breeds had similar carcass weight of 232.1 kg, at the average and exceeded their analogues of Black-and-White and Bestuzhev breeds by 7.3 kg (3.2 %) and 14.6 kg (6.7 %), respectively. The meat proportion in the carcasses of the calves was 78.5, 78.6, 78.1, 79.5, and 79.7, respectively. The remaining part comprises bones, tendons, and ligaments. Therefore, the nutritional value of the meat with bones of the beef calves (Hereford and Aberdeen Angus) is higher, since they have greater edible part.

The data of the chemical composition of the carcass flesh indicates the differences in the content of dry matter (DM) and its main components in Table 1.

Table 1

Chemical composition of carcasses meat from experimental animals[a]

Indices	Water, %	DM, %	Protein, %	Fat, %	Nutritional value of 1 kg of meat, MJ
Simmental (n = 18)					
Mean	69.61	30.39	18.88	10.58	7.31
s.e.m.	0.31	0.31	0.34	0.30	
p	*	*	ns	*	
Black-and-White (n = 18)					
Mean	70.35	29.66	18.60	10.12	7.13
s.e.m.	0.55	0.55	0.36	0.37	
p	**	**	ns	**	
Bestuzhev (n = 18)					
Mean	70.36	29.64	18.86	9.86	7.08
s.e.m.	0.46	0.46	0.52	0.34	
p	**	**	ns	**	
Hereford (n = 18)					
Mean	68.41	31.59	19.05	11.63	7.80
s.e.m.	0.34	0.34	0.37	0.35	
Aberdeen Angus (n = 18)					
Mean	68.02	31.98	19.24	11.54	7.80
s.e.m.	0.48	0.48	0.18	0.29	
p	ns	ns	ns	ns	

[a] Note: DM = dry matter; n = number of heads in each group;
s.e.m. = standard error of mean; p = probability; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ compared to data on the chemical composition of carcasses meat of Hereford cow breed.

So, the meat obtained from the Hereford and Aberdeen Angus animals contained more DM compared to the Simmental calves by 1.39 %, on average, to the Black-and-White ones – by 2.12 %, and to the Bestuzhevs – by 2.14 %.

The protein proportion in the carcass meat from the calves of all groups was similar and made 18.60-19.24 %. The meat from the beef calves, however, contained more fat. In particular, the young stock of Hereford had higher index of fat by 1.05 % than the animals in group I, by 1.51 % ($p < 0.05$) than the calves in group II, and by 1.77 % ($p < 0.05$) than the youngsters in group III.

This fact had a positive impact on the energy value of the meat. The fat to protein ratio in group I was 0.56:1, in group II – 0.54:1, in group III – 0.52:1, in group IV – 0.61:1, and in group V – 0.60:1. Consequently, only the meat from the Herefords and Aberdeen Anguses had recommended values. The meat from the animals of other breeds was relatively lean.

To study the chemical composition of the carcass flesh, the biochemical analysis of the lean tissue was conducted based on the eye muscle of loin in Table 2.

The data obtained show that no significant difference was observed according to the DM and protein content in the eye muscle of loin. However, the synthesis of the intramuscular fat proceeded in the calves of the Hereford and Aberdeen Angus breeds most intensively. According to this indicator, the animals in group IV exceeded their analogues in group I by 0.67 % ($p < 0.05$), in group II – by 0.68 % ($p < 0.05$), and in group III – by 0.82 % ($p < 0.05$).

Table 2

Biochemical composition and culinary-technological properties (CTP) of lean tissue based on the eye muscle of loin[b]

Indices	DM, %	Protein, %	Fat, %	Trypto-phane, mg %	Oxy-proline, mg %	PQI	WRC, %	TWL, %	CTP
Simmental (n = 18)									
Mean	23.39	20.62	2.31	364.40	58.40		66.51	35.34	
s.e.m.	0.30	0.34	0.16	16.26	0.70	6.24	0.25	0.25	1.88
p	ns	ns	**	ns	ns		**	***	
Black-and-White (n = 18)									
Mean	23.73	20.47	2.30	361.80	59.80		65.73	36.86	
s.e.m.	0.41	0.30	0.13	10.57	0.81	6.05	0.13	0.17	1.78
p	ns	ns	***	ns	*		***	***	
Bestuzhev (n = 18)									
Mean	23.32	20.18	2.16	362.30	59.20		66.24	35.12	
s.e.m.	0.34	0.13	0.12	11.50	0.35	6.12	0.36	0.18	1.89
p	ns	ns	***	ns	*		**	***	
Hereford (n = 18)									
Mean	24.52	20.55	2.98	366.20	56.90	6.43	67.82	33.22	2.04
s.e.m.	0.51	0.43	0.10	9.58	0.93		0.25	0.28	
Aberdeen Angus (n = 18)									
Mean	24.61	20.73	2.87	369.80	57.60		68.27	33.12	
s.e.m.	0.40	0.20	0.13	4.53	0.87	6.42	0.34	0.17	2.06
p	ns	ns	ns	ns	ns		ns	ns	

[b]Note: PQI = protein-quality indicator; WRC = water-retention capacity; BDA = boil down ability;
n = number of heads in each group;
s.e.m. = standard error of mean; p = probability; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ compared to data on the values of lean tissue of Hereford cow breed.

The Aberdeen Angus and Hereford calves were distinguished by the highest biological value of meat. In terms of this indicator, they were superior to the animals in groups I, II, and III, at the average, by 2.9, 6.1, and 4.9 %, respectively.

According to the water retention capacity of meat, the Black-and-White calves were inferior to the animals of Aberdeen Angus and Hereford breeds by 2.54 ($p < 0.001$) and 2.09 % ($p < 0.01$), respectively, with their boil down ability of meat to be higher by 3.34 ($p < 0.001$) and 3.64 % ($p < 0.001$).

A balanced amino acid composition is very important, primarily for essential amino acids. To construct the overwhelming majority of proteins in the human body, all 20 amino acids correlated are required. Moreover, a sufficient amount of essential amino acids is not so much important as their correlation, most closely resembling that in the proteins of the human body. The balance disorder in the amino acid composition of the dietary protein leads to disruption of the synthesis of self-proteins and changes the dynamic balance of the protein anabolism and catabolism to the decay predominance of the body's self-proteins, including the protein-clinging enzymes. The lack of one or another essential amino acid limits the use of other amino acids in the protein biosynthesis. Considerable excess of them leads to the formation of highly toxic metabolic products unused for amino acid synthesis [14].

Proteins are the most valuable food component, as they are involved in the critical functions of the organism. The main value of the proteins is their indispensability by other nutrients. In humans, the food proteins are cleaved to amino acids, some of them are split to organic keto acids, which are newly synthesized to amino acids and then to proteins [15]. These are so-called essential amino acidsis given in Fig. 1.

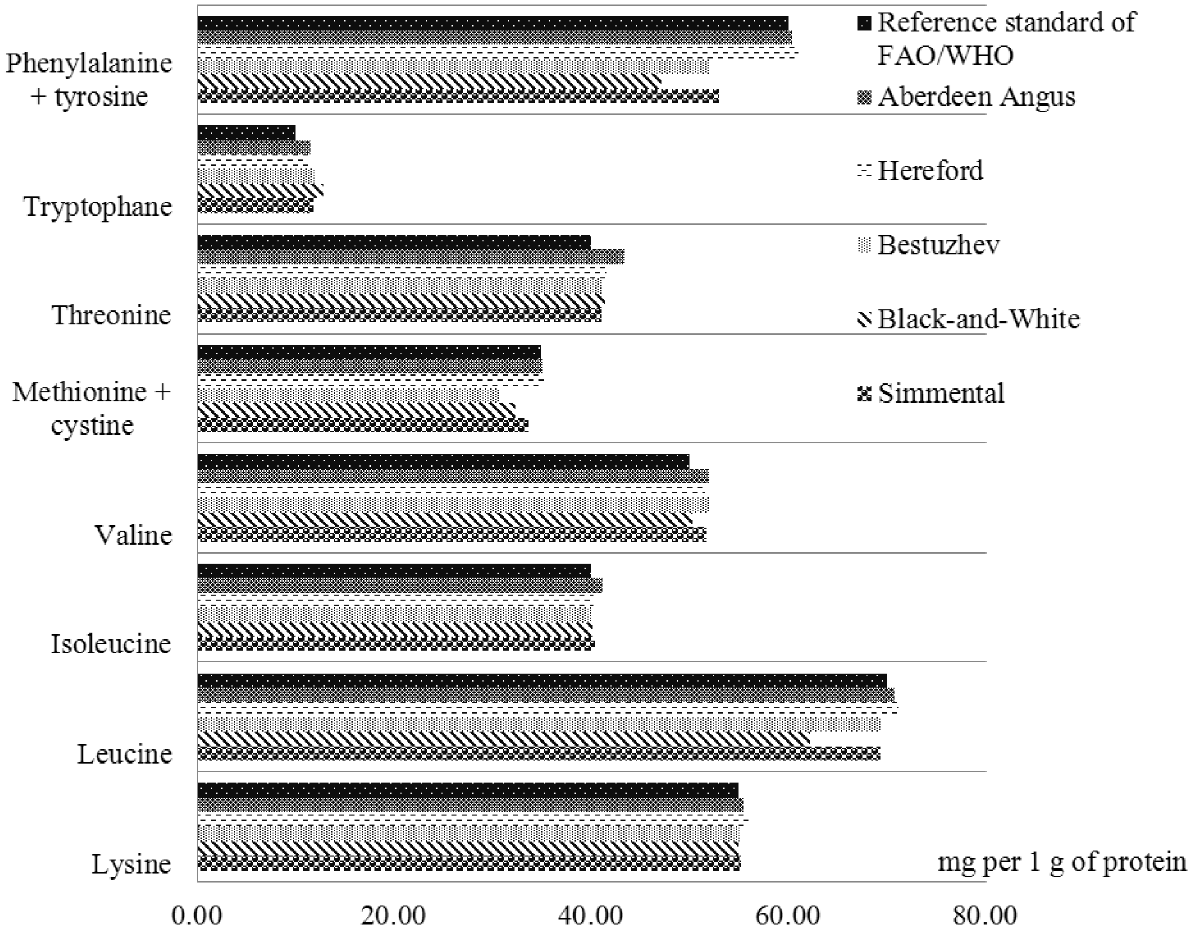

Fig. 1. **Content of essential amino acids in muscle proteins of calves of different breeds**

As evidenced by the results of the research studies, the content of all essential amino acids in the lean tissue proteins of the calves of Hereford and Aberdeen Angus breeds corresponded to the standards of WHO/FAO [16]. A lack of such acids as leucine, methionine, and phenylalanine was revealed in the meat proteins of the animals of Simmental, Black-and-White, and Bestuzhev breeds. According to the indicators, they were inferior to the calves in groups IV and V by 1.6 to 12.7, 4.3 to 12.5, and 4.0 to 22.8 %. Due to the lack of amino acids, the protein formation in the lean tissue is discontinued that leads to various disorders.

The biological value of proteins is determined by comparing the amino acid composition of the protein under study with the reference scale of amino acids of a hypothetically ideal protein or with the aminograms of high standard proteins. This criterion makes it possible to grade the food proteins in order of their comparative benefit for humans and animals [16]. The bioavailability of the food proteins depends largely on the content and the ratio of their constituent essential amino acidsis given in Fig. 2.

If the amino-acid score is below 100 %, this amino acid is limiting. The amino acid analysis revealed that the proteins of the beef from experimental groups I, II, and III contained limiting amino acid. These are leucine – 88.9 to 99.6 %, methionine + cystine – 88.0 to 96.0, and phenylalanine + tyrosine – 78.5 to 96.7 %. Due to the lack of the acids, the usefulness of the protein is limited.

At the deficiency of any essential amino acid, the use of other amino acids is limited. In groups IV and V, the amino-acid score of all amino acids was higher than 100 %, so, the lean tissue protein in these groups is complete.

Another indicator of the dietary protein quality is the coefficient of amino-acid score difference (CAAS), which indicates the average excess value of the amino-acid score of essential amino acids compared with the lowest level of any essential amino acid are summarized in Table 3.

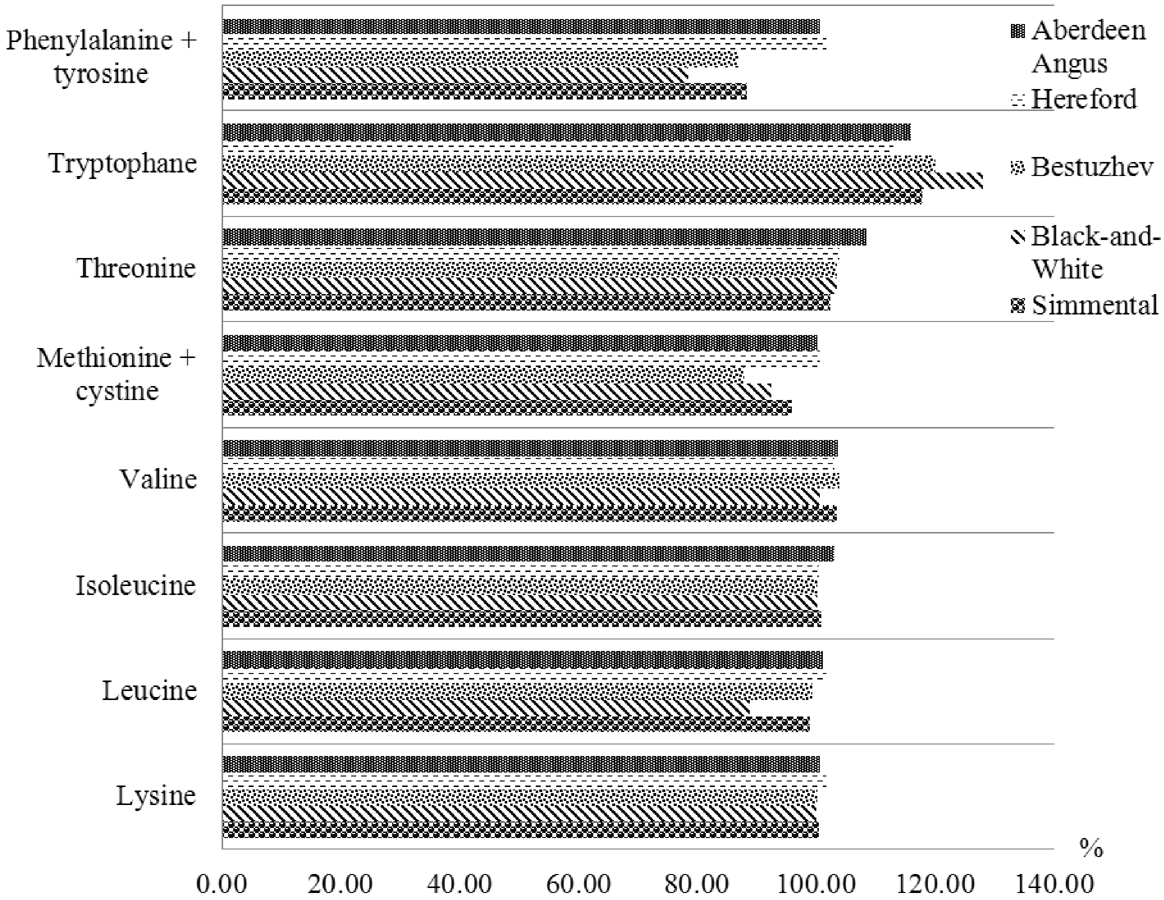

Fig. 2. **Amino-acid score**

In our studies, the lowest rate was registered in the beef calves. According to this indicator, they were inferior to the animals in groups I, II, and III by 0.95 to 5.6 %.

According to the results of the calculation of the biological protein value, the calves in groups IV and V had a more balanced ratio of essential amino acids. The meat of the animals in groups I, II, and III was noted for lower bioavailability due to higher content of methionine, tryptophan, and phenylalanine. So, the beef calves were inferior to the dairy calves in terms of methionine by 3.4 to 11.7 %, tryptophan – by 2.0 to 16.0 %, and phenylalanine – by 10.0 to 20.8 %. The sharp increase in one of the amino acids leads to the reduction in biological value of proteins.

Table 3

Biological value of protein in beef lean tissue[c], %

Amino acid	Simmental	Black-and-White	Bestuzhev	Hereford	Aberdeen Angus
Lysine[1]	0.41	0.07	0.23	1.80	0.70
s.e.m.	0.09	0.07	0.06	0.05	0.05
p	*	ns	ns	**	*
Leucine[1]	1.03	11.14	0.70	1.76	1.12
s.e.m.	0.11	0.14	0.09	0.12	0.10
p	**	ns	**	**	**
Isoleucine[1]	1.00	0.35	0.52	0.52	3.04
s.e.m.	0.07	0.05	0.08	0.05	0.06
p	*	ns	*	*	**

Table 3 (continued)

Amino acid	Simmental	Black-and-White	Bestuzhev	Hereford	Aberdeen Angus
Valine[1]	3.44	0.61	4.02	3.03	3.84
s.e.m.	0.09	0.11	0.13	0.08	0.12
p	**	ns	**	**	**
Methionine + cystine[2]	4.05	7.43	12.01	0.60	0.32
s.e.m.	0.08	0.15	0.10	0.11	0.09
p	**	**	ns	**	**
Threonine[3]	2.54	3.54	3.03	4.01	8.54
s.e.m.	0.12	0.10	0.15	0.09	0.11
p	ns	**	***	***	**
Tryptophane[4]	18.03	28.04	20.01	13.01	16.00
s.e.m.	0.03	0.05	0.05	0.04	0.05
p	**	**	**	ns	**
Phenylalanine + tyrosine[1]	11.70	21.53	13.23	1.70	0.70
s.e.m.	0.10	0.14	0.12	0.16	0.12
p	**	ns	**	**	**
$\sum(C_i - C_{\min})$[4]	42.02	72.42	53.61	28.12	34.10
s.e.m.	0.12	0.15	0.15	0.19	0.14
p	*	**	**	ns	*
CAAS[4]	5.22	9.10	6.67	3.49	4.24
s.e.m.	0.11	0.09	0.10	0.22	0.08
p	**	**	**	ns	*
Biological value[1]	94.78	90.90	93.33	96.51	95.76
s.e.m.	0.11	0.09	0.10	0.22	0.08
p	**	ns	**	**	*

[c] Note: s.e.m. = standard error of mean; *p* = probability; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ compared to data on the composition of fatty acids in intramuscular fat of ([1]) Black-and-White, ([2]) Bestuzhev, ([3]) Simmentaland([4]) Hereford cows breed.

It is important to emphasize that the content of essential amino acids is important not only for the biological value of the product, but also for the formation of a number of the meat quality indicators – tenderness, texture, taste, and others influenced by the aging process, with the amino and nonprotein nitrogen content to change resulting from the protein breakdown.

The nutritional properties are usually determined by the ratio between the saturated (SFA), monounsaturated (MUFA), and polyunsaturated fatty acids (PUFA). The higher the SFA content in fat, the firmer the fat and the lower its digestibility. Conversely, the elevated MUFA and PUFA level makes the fat susceptible to oxidation and rancidity, fat becomes softer with fatter structure, the data are presented in Table 4.

Table 4

Composition of fatty acids in intramuscular fat[d], %

Amino acid	Lipid formula	Simmental	Black-and-White	Bestuzhev	Hereford	Aberdeen Angus
Saturated						
Myristic[1]	14:0	2.35	1.52	1.71	2.43	2.75
s.e.m.		0.40	0.21	0.22	0.41	0.30
p		ns	ns	ns	*	**
Palmitic[1]	16:0	27.21	25.34	26.32	28.15	28.21
s.e.m.		1.35	1.23	1.29	0.67	0.79
p		ns	ns	ns	*	*

Table 4 (continued)

Amino acid	Lipid formula	Simmental	Black-and-White	Bestuzhev	Hereford	Aberdeen Angus
Stearic[2]	18:0	24.30	24.13	22.10	24.70	24.45
s.e.m.		0.27	0.21	0.24	0.21	0.18
p		**	**	ns	**	**
Total content[2]		53.86	50.99	50.13	55.28	55.41
s.e.m.		1.85	1.99	2.01	1.66	1.56
p		ns	ns	ns	*	*
Monounsaturated						
Myristoleic[1]	14:1	0.42	0.16	0.31	0.64	0.58
s.e.m.		0.01	0.06	0.04	0.01	0.01
p		*	ns	*	**	**
Palmitoleic[1]	16:1	2.11	1.85	2.47	2.17	1.99
s.e.m.		0.23	0.19	0.26	0.20	0.18
p		ns	ns	*	ns	ns
Oleinic[2]	18:1	42.32	40.24	40.15	44.61	43.78
s.e.m.		1.31	1.20	1.44	1.38	1.55
p		ns	ns	ns	*	*
Total content[1]		44.85	42.25	42.93	47.42	46.35
s.e.m.		1.63	1.25	1.29	1.46	1.35
p		ns	ns	ns	*	*
Polyunsaturated						
Linoleic[2]	18:2	3.16	2.47	2.03	4.53	4.90
s.e.m.		0.15	0.11	0.21	0.12	0.18
p		*	ns	ns	**	***
Linolenic[1]	18:3	0.23	0.20	0.25	0.31	0.42
s.e.m.		0.06	0.06	0.04	0.08	0.08
p		ns	ns	ns	ns	*
Arachidonic[1]	20:4	2.34	1.87	2.05	2.74	2.53
s.e.m.		0.51	0.22	0.36	0.28	0.24
p		ns	ns	ns	*	*
Total content[2]		5.73	4.54	4.33	7.58	7.85
s.e.m.		1.01	1.09	1.06	1.11	1.14
p		ns	ns	ns	*	*

[d] Note: s.e.m. = standard error of mean; p = probability; *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$ compared to data on the composition of fatty acids in intramuscular fat of ([1]) Black-and-White and ([2]) Bestuzhev cows breed.

The fatty acid composition analysis of intramuscular fat of the calves of the studied breeds showed that the meat from all the groups was characterized by a balanced composition of fatty acids.

The implication is that the meat of beef calves was more balanced in terms of the amino and fatty acid composition.

The results showed that the broth from meat of young animals was transparent, had yellowish color, pleasant aroma and taste in all groups compared.

Conclusions

Thus, the beef obtained at slaughter of young stock of different breeds was evaluated as complete and balanced raw material in the matter of amino acid composition. Containing all essential amino acids for the protein synthesis flow, the meat was qualified for human consumption. According to the results of the implementation, the beef obtained from the calves of Hereford and Aberdeen Angus breeds should be considered the most valuable.

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