TRENDS IN MEAT AND MEAT PRODUCTS MANUFACTURING

Polish Society of Food Technologists
Malopolska Branch

Faculty of Food Technology
University of Agriculture in Krakow

Department of Animal Products Technology

POLISH SOCIETY OF FOOD TECHNOLOGISTS

FACULTY OF FOOD TECHNOLOGY, UNIVERSITY OF AGRICULTURE IN KRAKOW

DEPARTMENT OF ANIMAL PRODUCTS TECHNOLOGY

4th International Conference on

'TRENDS IN MEAT AND MEAT PRODUCTS MANUFACTURING'

Joanna Tkaczewska, Piotr Kulawik, Władysław Migdał, Maria Walczycka, Ewelina Węsierska, Marzena Zając

(Editors)

MONOGRAPH

Krakow, 11-12 June 2015

The changes of biochemical properties of meat under the influence of physical and chemical factors after slaughter

Paska M.
Lviv National University of Veterinary Medicine and Biotechnologies named after S.Z. Gzhytskyi. Lviv, Ukraine.E-mail: maria_pas@mail.ru

Key words: pigments, meat properties, beef

Introduction

After the animal death the content and properties of muscle tissues change substantially. As a result of oxygen synthesis suspension, the metabolism and transformation of energy in tissues is broken. In the initial period autolytic changes appear, which are connected with the movement functions (reduction and relaxation of muscle fibers): intensive disintegration of carbohydrates (provides the synthesis of ATP), ATP (supplier of energy to myofibrils) and different changes of contractile apparatus. In this period of protein autolysis the specific changes that stimulate aggregation correlations occur. Furthermore, changes connected with the hydrolytic disintegration become more common.

In the basis of the autolytic meat changes lies the changes of the carbohydrate system, system of re-synthesis of ATP and the state of myofibril proteins that are the part of the contractile system. Changes in the meat are caused by the autolytic processes, which can occur in the meat due to the different methods of its processing, during the freezing and chilled storage, thawing, pickling, grinding etc. Character and properties of autolytic meat changes influence its quality and nutritional value.

The analysis of the food products value, detection of potential risks, connected with their contamination and deterioration must be based on the scientific basis and on the new methods of research. Thus, the research of meat usage with the features of PSE and DFD in the technology of emulsified sausages (PSE – pale, soft, exudative; DFD – dark, firm, dry; DCB – dark cutting beef) is very important and current. Assessment of the normal, PSE and DFD meat is necessary to obtain quality meat products production and their safety to the humans' health.

Materials and methods

The materials were beef meat samples, acquired directly after slaughter from two slaughterhouses from Lviv region: LLC "Polis" and JSC "Agramik". The animlas were divided into the following groups: bulls aged 18-24 months, bulls aged 24-36 months and cows aged 36-72 months. After the veterinary sanitation examination, the detailed analysis of the beef meat quality was carried out, where the appearance, color, smell and texture were evaluated. Additionally, the samples of muscle tissue was taken out for laboratory analysis of the general content of beef pigment. The analysis was performed using the extraction method on KFK (the length of wave 540 nm) using the chloroacetone solution.

The intensity of pH changes in the beef of NOR, PSE and DFD quality was also measured. The measurements were taken right after the slaughter and after 1, 12, 24 and 48 hours. The results of the research were evaluated taking into account the age and sex of slaughtered animals. The total of 240 samples from the longest muscle of spine of bulls brawns aged from 18 to 24 months, from 24 to 36 months and from cows of black and white breed aged from 36 to 72 months was analyzed. The temperature of maturation was 2-4 °C. Afterwards the following calculations were made: the dynamics of pH meat indicator, obtained from bulls aged from 18 to 24 months from the moment of slaughter and in the period of maturation depending on meat quality; the dynamics of pH indicator of meat, obtained from bulls aged from 24 to 36 months, from the moment of slaughter and during the period of maturation depending on the meat quality; the dynamics of pH indicator of meat, obtained from cows aged from 36 to 72 months from the moment of slaughter and during the period of maturation depending on the meat quality.

The proximate composition was performed the longest muscle in the spine of cattle of the beef after meat maturation in the temperature 2-4 °C during 24 hours.

Results and Discussion

Meat color is an important organoleptic quality indicator that depends on the pigment content. The results of organoleptic evaluation of beef meat show that the sensory properties of beef muscle differs among the studied samples. Thus, three major groups were determined with the different organoleptic features.

According to the existing beef meat classification, due to the quality indicators of abovementioned three groups of muscles we referred to beef NOR (normal), PSE and DFD quality.

NOR beef, obtained from bulls aged from 18 to 24 months had the best organoleptic indicators: elastic consistency, brightly-red color, well expressed, pleasant and specific for beef smell; the surface of a muscle tissue cut was dense, shiny, moderately moist, elastic; after maturation the skin of drying was quickly appearing; fat was shiny, firm and of white color, but in the animals of an older age (cows aged from 36 to 72 months) – of yellow color; tendons and joints of the limbs were hard, white, shiny, synovia is transparent; soup has good taste features, fragrant, specific for this kind of meat, fat balls are of the same size and spread evenly all over the surface.

Meat of bulls aged from 24 to 36 months differed only with color – it was pink-reddish and in cows – dark-red.

Organoleptic indicators of PSE beef meat, obtained from the animals of different age groups differ from the quality meat (NOR): had less elastic constituency, the surface of a cut was soft, well hydrated (exudative), color was pale-pink, the skin of drying was slowly appearing; fat was shiny, slightly with pale-yellow color; tendons and joints of the limbs were hard, white, less shiny, synovia is transparent. Considerable changes in fragrance indicators of soup from meat of these animals of different age groups were not obvious – less fragrant, turbid, fat balls were unevenly spread over the soup surface.

DFD beef had more dark color, in comparison with the quality beef: depending on the age, meat had reddish color (bulls aged from 18 to 24 months) or dark-reddish color (bulls aged from 24 to 36 months) and cows – with brown tint. Consistency of this meat is crumb like, the surface of a cut is dry, from low toughness in meat obtained from the younger animals, to high toughness in animals aged from 36 to 72 months. The skin of drying appeared after 6-12 hours after slaughter; fat is dim, firm of white-yellow color; tendons and joints of the limbs were hard, white, non-shiny, synovia is slightly dim. Soup is non-fragrant, untransparent and dim, fat balls were of different size and unevenly spread over the soup surface. Regardless the age groups, beef with the DFD defect had low taste quality, soup of this meat was non-fragrant and untransparent, depending on the age of animals – from turbid (bulls of 18-24 months) to considerable turbid in

older animals, fat balls were of different size and unevenly spread over the soup surface.

Meat color depends on the content of pigments. The general pigment content was determined in beef, obtained from animals of different age with the NOR (39 samples), PSE (42 samples) and DFD (39 samples) quality. The general pigment content in meat of different quality is shown in the table **1.**

Table 1. General content of pigments in beef of quality NOR, PSE and DFD after maturation

Age group of animals	General кількість проб	Content of pigments mg/cm^3		
		NOR beef,n=13	PSE beef, n=14	DFD beef, n=13
1 group	40	8,32+0,38 (7,83-9,00)	1,86+0,16*** (1,65-2,35)	15,54±0,53*** (14,70-16,20)
2 group	40	9,46±0,72 (8,73-10,45)	2,16+0,22*** (1,80-2,45)	17,7610,82*** (16,40-19,70)
3 group	40	11,89+0,68 (10,92-12,73)	2,65±0,32*** (2,05-3,40)	20,84±1,01*** (18,45-22,15)

*p<0,05, ** p<0,01, *** p<0,001,

As it is shown in the table 1, in the beef of NOR quality the general content of pigments ranged in average from 8,32±0,38 to 11,89+0,68 mg/cm^3 depending on the age group of animals. The greatest number of pigments was observed in the beef, obtained from cows -11,89 mg/cm^3; the least – 8,32 mg/cm^3 in meat from bulls aged from 18 to 24 months.

General content of pigments was the highest in DFD beef especially in red meat from cows – 20,84 mg/cm^3 that is why they had characteristic dark-red color. In meat from bulls aged from 18 to 24 months general content of pigments was 15,54 mg/cm^3; in meat from bulls aged from 24 to 36 months – 17,76 mg/cm^3

The content of pigments in DFD meat was higher in comparison with the NOR quality, obtained from bulls aged from 18 to 24 months for 86,7 % (p<0,001); in meat from bulls aged from 24 to 36 months – for 87,7 % (p<0,001); from cows – for 75,3 % (p<0,001).

The least number of pigments was in beef of PSE quality; from bulls aged from 18 to 24 months – 1,86 mg/cm^3 , from bulls aged from 24 to 36 months – 2,16 mg/cm^3, from cows – 2,65 mg/cm^3, that's why for this kind of meat is

peculiar pale-pink color. The content of pigments in meat of PSE quality, obtained from bulls aged from 18 to 24 months, was lower in comparison with high quality meat for 77,6 % ($p<0,001$); from bulls aged 24-36 months – for 77,2 % ($p<0,001$); from cows – for 77,7 % ($p<0,001$).

It is determined that the abovementioned indicators of beef depends on age and sex of the slaughtered animals and on the meat quality as well. The result of spread of NOR, PSE and DFD beef is shown in the table 2.

Table 2. The stage of spreading beef with the features of NOR, PSE and DFD

Group of animals	Number of brawns	NOR beef		PSE beef		DFD beef	
		Number of brawns	In percent	Number of brawns	In percent	Number of brawns	In percent
1 group	80	57	71,2	15	18,8	8	10
2 group	80	44	55	10	12,5	26	32,5
3 group	80	24	30	6	7,5	50	62,5
Total	240	125 .	52,1	31	12,9	84	35,0

Out of 240 researched brawns of beef – 125 (52,1%) were characterized as of high quality (NOR), out of them 57 brawns (71,2%) from young animals (bulls aged from 18 to 24 months).

The tendency of reduction of number of brawns with the increase of slaughtered animals age was observed.

PSE beef was in 12,9% of cases and DFD beef were in 35,0% of cases. DFD was found most oftenly in beef from animals from 36 to 72 months (62,5%) and PSE from animals from 18 to 24 months (18,8%).

One of the methods for checking the beef quality is the determination of pH. This indicator is widely used in meat processing industry of developed countries with the aim of constant control of meat quality. pH is used to get the necessary information about the potential meat safety and also about its technological fitness for classification according to PSE and DFD indicators.

The analysis of the dynamics of pH changes indicates that the pH in meat right after the animal slaughter in all analyzed groups was in frames of 6,8-6,9.

It was determined that the change of pH after 24-48 hours after slaughter depends on the age of slaughtered animal and on the meat quality as well, since

the most intense reduction of pH was observed in NOR quality meat of young animals. After 24-48 hours pH in these groups decreased between 5,6-5,8.

Beef from the older animals (cow) in NOR quality after 24-48 hours of maturation had pH of 5,7-6,0.

The indicators of pH of DFD beef in the period of maturation of 24-48 hours were the highest during the whole researched period, in comparison with the NOR beef and PSE. After 24-48 hours of maturation beef of DFD, obtained from young animals (bulls aged from 18 to 24 months) had pH of 6,2-6,4; from animals of medium age (bulls from 24 to 36 months) – 6,3; and from cows – 6,4-6,5.

PSE beef in all age groups after the period of maturation of 24-48 hours had the lowest pH; from young animals – 5,1-5,2; from bulls of medium age – 5,1 – 5,0; from cows – 5,3-5,2.

On the basis of performed researches can be made a conclusion that the pH characterize meat of NOR quality and PSE and DFD. In the first hour after the slaughter the indicators of pH differed among themselves in the samples of beef of NOR, PSE and DFD and depending on the age of the animals. Thus the indicators of pH after one hour after slaughter can be an indicator of the meat quality. Indicator of pH that characterize meat of NOR, PSE and DFD quality in different age groups is shown in the table 3.

Table 3. The indicators of pH of NOR, PSE and DFD beef, obtained after one hour of slaughter from different age groups of animals.

Beef quality	Age group of slaughtered animals		
	Bulls aged from 18-24 months	Bulls aged from 24-36 months	Cows aged from 36 to 72 months
NOR,	6,3±0,2	6,6±0,1	6,5±0,2
PSE,	5,7±0,1***	5,7±0,2***	5,8±0,2**
DFD	6,6±0,2	6,7±0,2	6,7±0,2

** $p<0,01$, *** $p<0,001$ in comparison to the degree of pH meat quality.

As it is shown in the table 3 the degree of pH of PSE beef differed from NOR beef quality. Nevertheless this degree in the DFD beef was insignificant in comparison with the NOR beef.

Indicators of pH after 24 hours of meat maturation are shown in the table 4.

Table 4. Indicators of pH of NOR, PSE and DFD beef, obtained after 24 hours of slaughter of different animals age groups

Beef quality	Age group of slaughtered animals		
	Bulls from 18 to 24 months	Bulls from 24 to 36 months	Cows aged from 36 - 72 months
NOR,	5,8±0,14	5,9±0,16	6,0±0,19
PSE,	5,2±0,09***	5,1±0,13***	5,3±0,12***
DFD	6,4±0,10***	6,3±0,15	6,5±0,12***

*** p<0,001, in comparison with the degree of pH of high quality meat.

Objective indicators that determine the meat quality, beside organoleptic indicators, are the chemical composition of the muscle – content of proteins, fats, carbohydrates, extract matters etc. The chemical composition of meat is influenced by species, breed, sex, age, fatness, peculiarities of feeding, meat quality and other factors.

This unit provides the characteristic of chemical content of the longest muscle in the spine of cattle depending on the age and sex of an animal after meat maturation in the temperature 2-4 °C during 24 hours (table 5). Beef of NOR, PSE and DFD quality were analyzed and divided into groups, depending on the different age groups of slaughtered animals.

Table 5. Chemical content of muscle tissue of bulls waged from 18 to 24 months after the meat maturation, (M± 1,26, n=12)

Indicator	NOR (high quality meat)	Meat with PSE features	Meat with DFD features
Humidity, %	76,24± 1,26	82,05 ± 2,56*	65,18±1,82***
Dry matter, %	23,76± 1,08	17,95±1,12**	34,82±1,34***
Ash, %	- 0,98±0Д4	1,0±0,26	1,1±0,22
Protein,%	20,48±1,68	14,72±1,84	31,32±1,98
Fat, %	1,85±0,48	1,68±0,35	1,73±0,41
Water holding capacity, %	64,96±2,32	43,14±2,24***	69,72±2,64
Tryptophan, mg%	477,36±14,56	342,08±16,88***	411,89±12,47**
Hydroxyproline, mg%	80,5 0±3,56	80,3±2,22	79,21±2,98
pH	5,8 ±0,2	5,2±0,2*	6,3±0,1*
Glycogen mg%,	334,05± 14,98	250,53±7,78***	136,19±3,12***

*p<0,05, ** p<0,01, *** p<0,001

As it is shown in the table 5 the most significant differences were found between the NOR PSE and DFD beef in the humidity, dry matter, water holding capacity, pH and the content of glycogen.

These indicators differed significantly among the studied samples of NOR, PSE and DFD beef. From technological point of view, humidity is the control indicator of great importance, since high level of humidity facilitates the reproduction of microorganisms and accelerates its deterioration. Moreover, the higher humidity of the meat, the lower quantity of dry matter, present in the meat (table 5). Thus, the nutrition value of such meat will be lower. Another important factor is the degree of water holding capacity of beef. Usually the optimal water holding capacity should be in the range of 64,96±2,32 %.

Thus the data, given in the table 5, show that the NOR, DFD and PSE beef differs in important features which influence the sanitation quality, nutrition value and technological suitability. This data indicates that the content of meat humidity was: NOR - 76,24±0,26 %, in PSE - 82,05 ±0,56 %, in DFD - 65,18± 0,42 %, and the biggest amount of dry matter was in DFD beef - 34,82±1,34 %. The degree of water holding capacity was also the highest in the DFD meat - 69,72±2,64 %, and the lowest in the PSE meat - 43,14±2,24 %.

Table 6 provides the data that characterize chemical composition of beef from bulls aged from 24 to 36 months.

Table 6. Chemical content of muscle tissue of bulls aged 24-36 months after meat, (M ± SD, n=12)

Indicator	NOR (high quality meat)	Meat with PSE features	Meat with DFD features
Humidity, %	74,42±2,08	79,86±2,42*	61,37±2,67***
Dry matter, %	25,58±1,29	20,14±1,68**	38,63±1,41***
Ash, %	1,02±0,24	1Д8±0,23	1,19±0,26
Protein,%	21,64±1,66	16,88±1,48	34,69±1,64
Fat, %	2,68±0,36	1,99±0,28	2,31±0,12
Humidity holding capacity, %	65,07±2,49	52,35±2,28***	71,44±2,66
Tryptophan, mg%	382,12±14,23	349,08±12,68*	358,08±14,89*
Hydroxyproline, mg%	73,88±2,45	78,35±3,12	74,60±2,88
Number of pH	5,9±0,2	5,3±0,2***	6,3±0,1**
Content of glycogen mg%,	231,34±10,11	224,71±6,85	126,80±2,10***

*p<0,05, ** p<0,01, *** p<0,001

In the tables 5 and 6 one can clearly see the difference in the beef of NOR, PSE and DFD in such parameters as the humidity, dry matter, water holding capacity, pH and glycogen content.

These indicators depend on the age group of the animals from which the meat was obtained. The content of humidity in the NOR beef, obtained from bulls aged 24-36 months was lower in average of 1,82%, in the beef of PSE quality – of 2,19% and in beef of DFD quality of 3,81%. The content of dry matter in the beef increased respectively in average for 1,82-3,81%. The content of glycogen was the lowest in average in the NOR beef – for 102,71 mg%, PSE - for 25,82 mg%, DFD - for 9,39mg%. The content of tryptophan was the lowest in average in NOR beef for 95,24 mg% in PSE beef – for 7,00 mg%, DFD beef – for 53,81 mg% which indicates the lower nutrition value of meat, obtained from bulls aged 24-36 months.

In case one would like to analyze the NOR, PSE and DFD beef according to the indicators of chemical composition, one could conclude that the highest amount of humidity was in the PSE meat (79,86%), the highest water holding capacity was in DFD meat (71,44%) and the lowest – PSE – 52,35%.

Characteristics of chemical content of beef, obtained from animals of older age (cows aged from 36 to 72 months) are shown in the table 7.

Table 7. Chemical content of muscle tissue of cows aged from 36 to 72 months after meat maturation, (M ± SD, n=12)

Indicator	NOR (high quality meat)	Meat with PSE features	Meat with DFD features
Humidity, %	69,18±2,21	75,24±2,88*	59,78±2,19*
Dry matter, %	30,82±2,26	24,76±1,04**	40,22±1,98***
Ash, %	1,18±0,06	1,24±0,14	1,20±0,12
Protein,%	26,03±1,88	20,25±1,48	35,35±1,69
Fat, %	3,44±0,18	2,74±0,16	3,64±0,22
Humidity holding capacity, %	57,33±2,44	48,78±2,99**	72,23±2,86
Tryptophan, mg%	360,94±14,88	264,32±12,21***	320,85±12,42*
Hydroxyproline, mg%	70,21 ±2,66	66,08±2,34	69,75±2,28
Number of pH	6,0±0,1	5,3±0,1**	6,4±0,1**
Content of glycogen mg%,	222,71±6,51	210,49 ±6,41	73,44±2,79***

*p<0,05, ** p<0,01, *** p<0,001

From the data in the table one can observe that beef, obtained from cows in comparison to the beef obtained from bulls, has lower amount of humidity in all analyzed groups of NOR, PSE and DFD meat and also the lowest water holding capacity in beef with PSE defect (48,78%).

Meat of NOR quality has the best chemical properties that characterize its high quality in comparison with the PSE and DFD beef.

Conclusions

Having analyzed the data it can be concluded that the pH value of PSE beef has differed from NOR and DFD beef, obtained from bulls aged from 18 to 24 months and from cows. Simultaneously this indicator in DFD meat obtained from bulls aged 24-36 months had the tendency to increase.

On the basis of carried research it can be concluded that the meat pH after the animal slaughter can be a good indicator for determination of beef quality after one hour and after 24 hours after slaughter.

The content of pigments in beef depends on the age and sex of slaughtered animals and on the color of meat.

References

1. Corah L.R., Ives S. Trace minerals in cow herd nutrition programs // *Agri-Practice*. -1992. –Vol. 13, № 4. – pp. 5-7.

2. Karpovs□kyy□ V.I. Osoblyvosti zmin pokaznykiv bilkovoho obminu u koriv riznykh typiv vyshchoi nervovoi diyal□ nosti pry z·hodovuvanni im tverdoho rozchynu dyhidrofosfativ mahniyu-tsynku [Features of changes in protein metabolism in cows of different types of higher nervous activity at feeding them solid solution of magnesium-zinc dihydrogen] / V.I. Karpovs□kyy□, D.I. Kryvoruchko, V.O. Trokoz, V.M. Kostenko, V.A. Tishchenko // *Visnyk Sums□ koho natsional□ noho ahrarnoho universytetu– Bulletin of Sumy National Agrarian University*. – 2007. – no 8(19). – pp. 49–52. (In Ukrainian)

3. W. Baumgartner Klinische Propädeutik der inneren Krankheiten und Hautkrankheiten der Haus-und Heimtiere. – Auflage, 2005, *Parey, Stuttgart*. – pp 220–240.

4. Holovach P.I. Vplyv pirydoksynu hidrokhlorydu na obmin bilka ta produktyvnist□ telyat molochnoho periodu vyroshchuvannya [Effect of pyridoxine hydrochloride on protein metabolism and productivity of dairy calves during growing] / Holovach P.I., Yaremko O.V. // *Naukovyy□ visnyk LNUVM ta*

BT imeni S.Z. Hzhyts□koho – Scientific Messenger of Lviv National University of Veterinary Medicine and Biotechnologies named after S.Z. Gzhytskyj – L□viv, 2007. – Vol.9, Part.2. – pp. 27–30. (In Ukrainian)
5. Hubs□kyy□ Yu.I. Biolohichna khimiya [Biological Chemistry]. – Kyiv, 2000. – pp.425–430. (In Ukrainian)
6. Paska M.Z. Bilkovyy□ status syrovatky krovi molodnyaku Volyns□koi□ myasnoi□ porody – Protein status of serum of young bull-calves of Volyn Meat Breed / *Zbirnyk naukovykh prats□ «Problemy zooinzhenerii□ ta veterynarnoi□ medytsyny» - Collected papers "Problems zooengineering and Veterinary Medicine"*, Kharkiv. – p.2.- vol.1.- pp.120-126. (In Ukrainian)
7. Paska M.Z. Fiziolohichnyy□ status orhanizmu buhay□tsiv Volyns□koi□ myasnoi□ porody zalezhno vid typiv vyshchoi□ nervovoi□ diyal□nosti [The physiological status of the organism of bull-calves of Volyn Meat breeds depending on the type of higher nervous activity] / *Naukovo-tekhnichnyy□ byuleten□ - Scientific and Technical Bulletin* // vol.12., no 3,4.- L□ viv,2011.- pp. 29-35. (In Ukrainian)
8. Paska M.Z. Obmen belkov syrovatky krovy bychkov volynskoy□ myasnoy□ porody raznykh typov vysshey□ nervnoy□ deyatel□nosty [Metabolism of protein of blood serum of bull-calves of Volyn meat breed different types of higher nervous activity] / *Mezhdunarodnyy□ vestnyk veterynaryy - International messenger of veterinary*.- Sank-Peterburh.- no 2.- 2013. pp. 55-60. (In Russian)
9. Svyrydenko N.P. Morfolohycheskye y byokhymycheskye pokazately krovy molodnyaka krupnoho rohatoho skota myasnykh porod [Morphological and biochemical parameters of blood of young cattle meat breeds]: *Naukovi dopovidi NAU - Scientific reports NAU* / N. P. Svyrydenko. – 2007. – 2 (7). – pp. 36–39. (In Russian)
10. Vlizlo V.V., Fedoruk R.S., Ratych I.B. et al. Laboratorni metody doslidzhen u biolohiyi, varynnytstvi ta veterynarniy medytsyni [Laboratory methods of investigation in biology, stock-breeding and veterinary] : Dovidnyk – Reference book ; Za red. V. V. Vlizla – Edited by V. V. Vlizlo. Lviv : SPOLOM, 2012, 764 p. (in Ukrainian).
11. Vukasinovic N. Implementation of a routine genetic evaluation for longevity based on survival analysis techniques in dairy cattle populations in Switzerland / N. Vukasinovic, J. Moll, L. Casanova // J. Dairy Sc. - 2001. - V. 84, № 9. - P. 2073 – 2080.

12. Patten L.E. Chemical properties of cow and beef muscles: Benchmarking the differences and similarities / L.E. Patten, J.M. Hodgen, A.M. Stelzleni, C.R. Calkins, D.D. Johnson, B.L. Gwartney // Journal. Animal Science - 2008- Vol. 86: - N 2.- P.1904-1916.
13. Phocas F. Genetic parameters for birth and weaning traits in French specialized beef cattle breeds / F. Phocas, D. Laloë // Livestock Production Science. – 2004. – Vol. 89, Issues 2-3. – P. 121-128.
14. Selektsiy□no-henetychni ta biolohichni osoblyvosti aberdyn-anhus□koi□ porody v Ukraini : Monohrafiya [Selection and genetic and biological characteristics of the Aberdeen-Angus breed in Ukraine: Monograph] / Y□. Z. Sirats□kyy□, V. O. Pabat, YE. I. Fedorovych ta in.; Za red. Y□. Z. Sirats□ koho i YE. I. Fedorovych. – K.: Nauk. svit, 2002. – pp.120–125. (In Ukrainian)
15. Plokhynskyy□ N. A. Byometryya [Biometrics].- M.- 1978.- 250 s. (In Russian)
16. Kokorina E.P. Uslovnyye refleksy i produktivnost' zhivotnykh [Conditioned reflexes and animal productivity]. - M. Agropromizdat. - 1986. – 335 p. (in Russian)
17. Metodicheskiye rekomendatsii po otsenke myasnoy produktivnosti i kachestva m'yasa krupnogo rogatogo skota. VASKHNIL. [Guidelines for assessing the productivity and quality meat m'yasa cattle. Agricultural Sciences] - M., 1990. - 86 p. (in Russian)
Blaster K.L. The energe metabolism of ruminants. 2-nd ed.Hutchinson scientific and technical. London,1967.
18. Blaster K.L. The energe metabolism of ruminants. 2-nd ed.Hutchinson scientific and technical. London,2007.- p.456-500