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Hereford and Simmental Cattle Breeds in Siberia: Implementation of the Adaptive and Productive Potential in the Cold Climate

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***Abstract*:This study was aimed at studying the biological characteristics of the calves of the Hereford and Simmental breeds, and crosses of these breeds in Siberia. The article discusses the peculiarities of metabolism and utilization of nutrients, growth rate, meat productivity and quality, feed conversion in groups of calves up to 15.5 months of age due to the breed identity in the keeping conditions in light facilities and cold climate. Similarity has been noted in the parameters of gas-and-energy metabolism in Hereford and crossbred calves, including their seasonal dynamics. During the experimental period, a seasonal downward trend was noted in the heart rate of Hereford calves by 11.4 %, and respiration rate — by 33.8 %. In the Simmental peers, these figures decreased by 12 and 37.2 %, respectively, in hybrids — by 6.1 and 29 %. The seasonal decrease in the body temperature in Hereford and crossbred animals by 2.4 – 2.5 %, in Simmentals — by 1.3 %, and increased heat production by Hereford animals and their crosses — by 20.9 and 20.1 % (P<0.01), compared to the Simmental peers, were noted. In terms of the content of hemoglobin, Hereford calves (116.5 ± 3.6 g/l) and Hereford × Simmental hybrids (114.0 ± 5.1 g/l) tended to be superior to Simmental calves (103.5 ± 5.4 g/l). No significant difference in the erythrocytes count in the blood of calves was found between the groups. In all ages, Simmental calves were inferior to their Hereford and crossbred peers in terms of the content of total protein and albumin in the blood serum. By the content of globulins in the blood serum, no differences were found between the groups. The coefficients of nutrients digestibility due to balanced feeding was relatively high in all groups. Hereford × Simmental hybrids were superior to their Simmental counterparts by the organic matter digestibility by 3.0 % (P<0.01). The most significant difference in the live weight was observed between Simmental and crossbred calves (P<0.01). The average daily gain of the hybrids over the entire study period was greater by 25.6 and 15.2 % than that of purebred Simmental and Hereford calves. Accordingly, Hereford × Simmental calves had an advantage over Herefords in terms of the slaughtering weight by 5.4 %, and over Simmentals — by 22.1 %. The energy value of the meat of purebred Herefords and crossbred calves was higher by 8.4 % than in purebred Simmentals.*

The conclusion has been made about the prospects of using Herefords and their crosses with Simmentals for the sustainable development of beef cattle breeding in the conditions of Siberia.

***Keywords*: beef cattle, Hereford breed, Simmental breed, crossbred animals, energy metabolism, meat yield, feed conversion.**

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I. INTRODUCTION

Sustainable development of meat cattle breeding in Russia is one of the most important areas in ensuring food security. Meat production is growing annually around the world due to increased meat consumption per capita and increasing population [1]. Increased demand for meat opens wide market opportunities for the producers of livestock breeding products. Therefore, in the coming years, the development of the domestic beef cattle industry will be one of the strategic areas [2].

Currently, in the meat industry, there are many breeds of various productivity lines, and crossbred combinations are used as a source of meat [3]. In Russia, the major part of beef is produced by dairy and dairy-meat breeds, of which the most common is the Simmental breed. This breed has well acclimatized in various climatic zones of the country and ranks second after the black-and-white breed. An important role in the development of meat cattle breeding is played by the Hereford breed, which is the most common in the world. Due to its high acclimatization abilities, the breed is widely met on all continents of the globe. The success of adaptation and potential productivity of the Hereford breed in Siberia depends on the forage base, the availability of pastures, and other factors [4].

Studying the metabolism is one of the most important elements in resolving the problem of managing individual development of agricultural animals. Many studies have shown that productive qualities of the animals directly depend on the level and the nature of the metabolic processes in the organism, the diets, the breed [5, 6], and the degree of using nutrients in the feed in the extreme climatic conditions [7, 8].

From the point of view of the urgent mobilization of the adaptive potential of the organism, studying cattle adaptation to extreme conditions, such as low temperatures, and deep snow cover is of great scientific and practical interest. Developing meat cattle breeding in Siberia is an important factor for ensuring the sustainable development of rural areas. In this regard, studying the comparative efficiency of using beef cattle of various breeds on large natural grasslands, which are numerous in the area, is of particular interest.

The research was aimed at studying the biological and economically useful characteristics of young Hereford and Simmental animals and their crosses kept in light-structured facilities.

II. PROPOSED METHODOLOGY

A. General description

An experiment in rearing and fattening animals at the age between 8 and 15.5 months was performed in Eastern Siberia at a specialized cattle-breeding farm. The objects of the study were Hereford (group 1), Simmental (group 2) calves, and hybrids of these breeds (group 3). In the autumn, groups of calves with the live weight corresponding to the average value for the herd were formed, 30 animals in each group. The observation period lasted until the late spring of the next year. The ambient temperature ranged from +10 to -40 ^{o}C

B. Algorithm

The biological peculiarities (nutrients digestibility, gas-and-energy metabolism, hematologic and biochemical parameters of the blood), as well as the meat quality of the animals were studied in six animals from each group.

The animals were kept loose at light-structured facilities (timber-paneled three-wall structures) with free access to the backyard feeding area at the rate of 15 m^2 per animal, with the feeding front of 0.5 – 0.6 m per animal. For rest, hills were made with the use of wind hedges. The conditions of the experiment corresponded to the Russian recommendations for farm animals' care and feeding. The diets in the experimental groups were the same and adjusted monthly. Watering was performed with the use of group drinkers with heating.

The intensity of the energy exchange in the calves at the age of 14 months was studied using the masking method. Analysis of the samples of inhaled and exhaled air for the content of oxygen and carbon dioxide was performed on Douglas-Holden gas analyzer. The lungs ventilation volume, the heart rate, the depth of respiration through the lung volume to the respiratory rate relation, the respiratory ratio as the ratio of carbon dioxide exhaled to the volume of oxygen consumed were accounted for on the first day between 16.00 and 18.00, on the second day — between 9.00 and 11.00. The body temperature was measured rectally.

The blood was studied at the end of the experiment. Blood samples were taken from the subcaudal vein of the animals in the morning before feeding. Hematologic studies were performed on PCE90Vet analyzer; the leukocytes count (10^9/l), erythrocytes count (10^{12}/l), and the level of hemoglobin (g/l) were determined. The biochemical parameters (total protein (g/l), albumin, and globulin fractions, Ca, P) were determined on Stat Fax 3300 analyzer. The protein ratio was calculated via the albumin to globulin content relation.

Nutrients digestibility in the diets was determined by the ratio of consumed with the feed and excreted with the feces dry organic matter, protein, fat, fiber, and nitrogen-free extractives (NFE). In the balance experiment, the metabolism of nitrogen, calcium, and phosphorus was studied in calves of various groups at the end of the experiment.

The animals' meat productivity indicators were studied at the age of 15.5 months by check slaughtering of six animals from each group and analyzing the quantitative and morphological composition of the carcasses by the following indicators: the weight of steam carcass, the content of the internal fat, the muscle tissue yield, the slaughter weight, the slaughter yield; the energy and nutritional value of the meat. The meatiness coefficient was determined using the muscle to bone tissue ratio. The protein quality indicator (PQI) was calculated based on the tryptophan to hydroxyproline content ratio. The meat nutritional value (MNV) was determined as the percentage of the amount of muscle and fatty tissues to the content of bone and connective tissues, multiplied by the PQI.

The obtained results were processed by the methods of descriptive statistics, a one-way ANOVA test with the use of Statistica 10 software. The veracity of the difference between the average values of the studied parameters was determined using Fisher's criterion.

III. RESULT ANALYSIS

Studying the physiological parameters allows to some extent judge about the animals' adaptation to specific climate conditions. It is known that body temperature, heart rate, and respiration depend on age, gender, and the feeding and keeping conditions. No significant difference was found between these indicators, depending on the breed of the animals in the studies (Table 1).

Table 1: Seasonal dynamics of physiological parameters of the calves of various groups

Indicator	Season	Group		
		1	2	3
Body temperature, °C	Autumn	39.4 ± 0.25	39.3 ± 0.17	39.4 ± 0.05
	Spring	38.9 ± 0.12	38.6 ± 0.16	38.5 ± 0.06
Heart rate	Autumn	87.9 ± 3.28	89.2 ± 3.56	85.0 ± 5.23
	Spring	77.9 ± 2.02	78.3 ± 2.18	79.9 ± 0.94
Breath rate	Autumn	31.7 ± 1.33	30.2 ± 0.68	30.4 ± 1.07
	Spring	21.5 ± 0.96	21.3 ± 1.14	21.5 ± 0.63

During the experimental period, a seasonal downward trend was noted in the heart rate of Hereford calves by 11.4 %, and respiration rate — by 33.8 %. In their Simmental peers, these figures decreased by 12 and 37.2 %, respectively; in hybrids — by 6.1 and 29 %. The seasonal decrease in the body temperature was noted in Hereford and crossbred animals by 2.4 – 2.5 %, and in Simmentals — by 1.3 %.

The authors have studied the gas-and-energy exchange in Hereford and Simmental calves, and in their crosses (Table 2).

Table 2: Gas-and-energy exchange in the calves from various groups at the age of 14 months

Indicator	Group		
	1	2	3
Ambient air temperature, °C	-14.8	-14.8	-14.8
Body temperature, °C	38.6	38.9	39.0
Breath rate	26.8 ± 1.45	27.0 ± 1.60	26.8 ± 1.01
Heart rate	76.3 ± 3.82	78.6 ± 2.25	78.5 ± 2.27
Depth of breath, l	2.4 ± 0.65	2.0 ± 0.41	2.4 ± 0.33
Lungs ventilation, l/min.	51.8 ± 4.41	43.1 ± 6.69	51.4 ± 6.13
O_2 absorption, l/min.	2.2 ± 0.26	1.85 ± 0.31	2.2 ± 0.33
CO_2 exhaling, l/min.	1.95 ± 0.77	1.65 ± 0.25	1.95 ± 0.26
Respiratory coefficient	0.88 ± 0.15	0.89 ± 0.01	0.88 ± 0.15
Heat production, MJ	66.8	55.2	66.3

A statistically veracious difference was noted between Hereford, Simmental, and crossbred calves in terms of the lungs ventilation volume (P<0.05).

By the amount of absorbed oxygen and exhaled carbon dioxide, the quality of the oxidation processes is determined. The respiratory coefficient, which characterizes the volume ratio of exhaled carbon dioxide to the absorbed oxygen during this period in Hereford, Simmental, and crossbred calves, was almost the same.

An increased heat production in Hereford calves and their crosses by 20.9 and 20.1 % (P<0.01) was found, compared to the Simmental peers.

The metabolism in the organism is closely related to the level of the hematologic parameters. In terms of the content of hemoglobin, Hereford calves (116.5 ± 3.6 g/l) and Hereford × Simmental hybrids (114.0 ± 5.1 g/l) tended to be superior to Simmental calves (103.5 ± 5.4 g/l). The content of erythrocytes in the blood of calves of various breeds ranged between 5.95 and 6.2 million/mm^3. No veracious differences were found between the groups.

The results of the study show that with the increase in the average daily gains in the blood of animals, the amount of total protein (6.65 – 7.45 g/%) and especially the albumin fraction (43.0 – 44.5 %) also slightly increases. In all ages, Simmental calves were inferior to their Hereford and crossbred peers in terms of the content of total protein and albumin in the blood serum. By the content of globulins in the blood serum, no differences were found between the groups. The protein coefficient of Simmental calves was 0.75; of Hereford × Simmental calves — 0.78, and Hereford calves — 0.84. The level of calcium in the blood serum varied in the range between 2.62 – 3.06 mmol/l, that of inorganic phosphorus — between 1.62 – 1.71 mmol/l, which corresponded to the reference values [9].

The efficiency of using nutrients in the feeds was largely associated with their digestibility. The coefficients of nutrients digestibility due to balanced feeding were relatively high in all groups (Table 3). Hereford × Simmental hybrids were superior to their Simmental counterparts by the digestibility of organic matter by 3.0 % (P<0.01). A tendency to increase the consumption of protein by Hereford and crossbred calves, compared to Simmental calves, was noted. Compared to Simmentals, crossbred calves digested fat, fiber, and NFE better (P<0.05).

Table 3: Digestibility of nutrients in the diets, %

Indicator	Group		
	1	2	3
Dry matter	69.9 ± 0.45	68.0 ± 0.85	71.0 ± 0.85
Organic matter	71.5 ± 0.55	69.3 ± 0.80	72.3 ± 0.80
Protein	67.0 ± 0.25	65.7 ± 1.20	68.0 ± 1.55
Fat	68.9 ± 3.65	67.7 ± 1.10	70.2 ± 0.60
Fiber	66.8 ± 0.20	65.0 ± 1.00	68.2 ± 0.70
NFE	74.8 ± 0.85	72.1 ± 1.70	75.3 ± 1.20

In young animals, protein is known to be used mainly in the formation of the skeletal muscles. It was, therefore, important to trace the transformation of feed protein in the organisms of experimental calves. For this purpose, the authors studied the metabolism of nitrogen, as well as that of calcium and phosphorus. In the experiment, a positive balance of nitrogen, calcium, and phosphorus was found in the animals in all groups (Table 4). A slightly greater amount of nitrogen was emitted from the organism of Hereford and Hereford × Simmental calves, while Simmentals consumed this element in the diet less by 3.6 %. A tendency to increase the daily nitrogen balance was noted in crossbred and Hereford calves by 20.1 and 12.8 %, compared to their Simmental counterparts.

The balance of calcium and phosphorus in the animals in the studied groups was positive. It should be noted that greater deposition of calcium and phosphorus was observed in Hereford × Simmental and Hereford calves, compared to Simmentals.

Table 4: The average daily balance of nitrogen, calcium, and phosphorus in the calves in various groups, g

Indicator	Group								
	1			2			3		
	N	Ca	P	N	Ca	P	N	Ca	P
Received with feed	200.4	97.9	46.9	193.2	90.0	46.0	200.8	97.4	46.0
Excreted: with feces	66.0	72.5	30.1	66.3	67.0	31.1	64.1	69.4	27.8
with urine	101.9	0.1	0.7	98.1	0.1	0.8	102.0	0.1	0.7
total	167.9	72.6	30.8	164.4	67.1	31.9	166.1	69.5	28.5
Balance (±)	+32.5	+25.3	+16.1	+28.8	+22.9	+14.1	+34.6	+27.9	+18.4
Digested: from the received feed, %	16.1	25.8	34.2	14.9	25.6	26.2	17.2	28.6	39.2
from digested feed, %	24.2	-	-	22.7	-	-	25.3	-	-

On average during the growing period from 8 to 15.5 months of age, the experimental calves consumed the following amounts of nutrients: Herefords — 17,605.0 MJ of

metabolizable energy and 179.9 kg of digestible protein; Simmentals — 17,368.5 MJ of metabolizable energy and 173.7 kg of digestible protein, and Hereford × Simmental — 18,181.5 MJ of metabolizable energy and 185.11 kg of digestible protein.

Intensive metabolism had a rather positive effect on the productive performance of the calves from 8 to 15.5 months of age and had a significant effect on the live weight of the experimental animals, which was quite high in all experimental groups both at the age of 12 and 15.5 months (Table 5).

Table 5:Age-related changes in the live weight of the experimental calves

Breed, stock	Live weight at the beginning of the experiment, kg	Age, months				Average daily weight gain, g
		12		15,5		
		Live weight, kg	gain, kg	Live weight, kg	gain, kg	
Hereford	199.0 ± 1.75	320.7 ± 2.15	121.7	436.7 ± 1.95	116.0	1,043
Simmental	188.5 ± 1.80	299.9 ± 1.65	111.4	394.0 ± 1.45	94.1	905
Hereford × Simmental crosses	197.8 ± 2.30	328.2 ± 3.50	130.4	456.0 ± 7.60	127.8	1,137

The most significant difference in the live weight was observed between Simmental and crossbred calves (P<0.01). Accordingly, the average daily gain of the hybrids over the entire study period was greater by 25.6 and 15.2 % than that of purebred Simmental and Hereford calves.

To study the meat productivity and meat quality of experimental calves of various breeds, check slaughtering of six animals in each group was made (Table 6).

Table 6: Meat productivity of calves of various breeds at the age of 15.5 months

Indicator	Group		
	1	2	3
Pre-slaughter weight, kg	405.1 ± 5.85	363.3 ± 5.4	422.2 ± 4.8
Weight, kg: steam carcass	222.6 ± 8.35	190.6 ± 3.4	235.8 ± 7.85
internal fat	16.7 ± 0.61	16.1 ± 1.06	16.5 ± 0.58
Slaughter weight, kg	239.3 ± 4.48	206.7 ± 2.23	252.3 ± 4.21
Slaughter yield, %	58.1	56.9	59.8
Weight of skin, kg	37.4 ± 0.22	34.5 ± 0.43	38.3 ± 0.40
The amount of boneless meat in the carcass, %	81.4	78.8	81.1
Energy value of the meat, MJ/kg	9.79	9.03	9.78
Meatiness coefficient	4.4	3.75	4.3
Protein quality index	5.9	5.9	6.15
Meat nutritional value	24.15	20.1	24.3

Carcasses of the calves in all groups were characterized by good development of the muscle tissues and were classified as top fatness. Hereford × Simmental calves had higher slaughter weight, which was by 5.4 % higher than that in Herefords, and by 22.1 % higher than that in Simmentals, respectively. Their superiority in terms of the slaughter yield to Herefords was 1.7 %, and to Simmentals — 2.9 %. The energy value of the meat of purebred Herefords and crossbred calves was higher by 8.4% than in purebred Simmentals.

The relative content of boneless meat in the carcasses of Herefords and crossbred animals was almost the same, and by 2.6 % higher than in Simmentals. Accordingly, the highest coefficient of meatiness was noted in the calves from the same groups.

The energy and nutritional values of the meat of Hereford and crossbred calves were higher than those of their Simmental peers. With that, a tendency to improving the quality of protein was marked in crossbred calves, compared to the purebred animals.

The better digestibility and utilization of nutrients from the feed by Hereford and crossbred calves contributed to an increased bioconversion of protein and energy from the feed into the meat products.

IV. DISCUSSION

Cattle growth, development, and formation in the postembryonal period mainly occurred according to the genetic properties of the animals. However, environmental factors also had a major effect on the speed of growth, development, and formation of the tissues and organs, especially in the conditions of adaptation.

As a result of the adaptation process, animals were exposed to the effects of stress factors that reduced their resistance, well-being in general [10, 11], and consequently, decreased the efficiency of using young pedigree cattle.

When young animals of beef cattle are kept during the stall period in light structured facilities and pens, the temperature of the environment is one of the main factors that affect metabolism, since a significant part of the energy produced by the body is used for maintaining the body temperature.

In cattle, the level of energy metabolism naturally increases with decreasing the temperature below the limits of the thermoneutral zone. Increasing heat production through increased energy metabolism is the main method of protection against decreasing body temperature. In the studies, this value was higher in Herefords and their crosses than in their Simmental peers.

An inverse relationship exists between the ambient temperature and the intensity of the metabolic processes in the animal organism: with decreasing the temperature, the level of metabolic processes increases, and with increasing the temperature, it decreases. If the ambient temperature is below the thermoneutral (critical) zone, the animals experience stress from the cold. They lose a significant amount of heat per unit of the body surface, and in the case of insufficient intake of nutrients, the organism increases heat production at the expense of the weight gain [12] and productivity. For instance, for dairy cattle, the upper critical temperature at which thermal stress is manifested, according to Herbut et al. (2015), was determined to be +24 – 27 °C [13]. Angrecka et al. (2015) found that the cold stress in dairy cows started manifesting itself as early as at 0 °C [14].

Animals of the Hereford breed feature well expressed thermoregulation, the ability of the organism to maintain constant internal conditions upon external changes (homeostasis), especially upon abrupt changes in the temperature at the junction of the seasons. This may happen, on the one hand, due to the changes in the regulatory mechanisms of the muscle tissue (cold adaptation enhances the processes of thermoregulation) [15], and, on the other hand, due to the formation of a certain structure of hair in the animal. Perhaps, the underdeveloped winter hair in Simmentals did not let them stay in the open during bad weather, which affected the intake of feed and nutrients from the diets. Heat exchange in the hybrids is probably regulated the same way as in Herefords. These two groups were characterized by similar seasonal changes in the body temperature. This is also evidenced by a significant increase in heat production in Herefords and crossbreeds, compared to Simmentals.

The use of fats is associated with the consumption of oxygen. The amount of absorbed oxygen and exhaled carbon dioxide characterizes the quality of the oxidation processes. The respiratory coefficient, which characterizes the volume ratio of the exhaled carbon dioxide to the absorbed oxygen during this period, was almost the same in Hereford, Simmental, and crossbred calves.

No significant effect of the breed on the respiratory rate and heart rate was found in the experimental bulls. During the experimental period, the seasonal trend to decreasing these symptoms was noted, which has been confirmed by other researchers [16].

In general, the gas-and-energy metabolism in all groups of animals indicates better adaptation of Herefords to low temperatures and confirms the inheritance of these qualities by hybrids.

Although the main metabolism in the animals is the most inertial, compared to the behavioral and vegetative reactions, some differences are noted in the basic physiological indicators of the animals in various groups. The similarity of the compensatory mechanisms of adaptation in Herefords and crossbreeds is confirmed by the tendency to their superiority to Simmentals in the level of hemoglobin, total protein, and albumin.

The hematological and biochemical blood parameters depend on the metabolism and characterize the potential productivity and viability of an animal. The leading place in the biochemical metabolism of animals is taken by blood proteins and their fractions. The results have shown that with the increase in average daily weight gains, a tendency to increase total protein and especially albumin fraction is observed in the blood of the animals. With that, in all ages, Simmental calves were inferior to their Hereford and crossbred peers in terms of the content of total protein and albumin in the blood. The protein coefficient (the albumin to globulin ratio) in Simmental calves was slightly lower than in Herefords and crosses.

On average over the growing period, the experimental crossbred calves and Herefords consumed the greatest amount of nutrients. The coefficients of nutrients digestibility due to balanced feeding was relatively high in all groups. For instance, Hereford × Simmental hybrids were superior to their Simmental counterparts by the digestibility of organic matter.

V. CONCLUSION

In the experiment, a positive balance of nitrogen, calcium, and phosphorus was found in the animals in all groups. A tendency to increase the daily nitrogen balance was noted in crossbred and Hereford calves, compared to their Simmental counterparts. The peculiarities of using nitrogen by the calves are consistent with the results of assessing their growth throughout the experiment, where the average daily gain of Hereford calves was 1,050 g, of Simmental calves — 930 g, and of hybrids — 1,160 g.

The balance of calcium and phosphorus in the animals in the studied groups was positive. It should be noted that greater deposition of calcium and phosphorus was noted in Hereford × Simmental and Hereford calves, compared to Simmentals.

The intake of the feed energy into the organisms of the experimental calves was virtually the same, and its use for the growth of the body weight was different. These differences are determined by lower losses of energy in Herefords and their crosses, compared to Simmentals. The feed consumption per one kg of the weight gain in the group of crossbred calves was lower than in Herefords and Simmentals by 6.0 and 19.8 %, respectively.

In the studies [17] aimed at assessing different levels of metabolizable energy consumption during the fattening period, Herefords also had an advantage, compared to Simmentals.

Carcasses of the calves in all groups were characterized by good development of the muscle tissues and were classified as top fatness. The highest coefficient of meatiness, energy, and nutritional value of meat was observed in Herefords and crossbred animals. A higher slaughter weight was observed in Hereford × Simmental calves. The superiority of crossbred animals to both parent forms in terms of the live weight and the average daily gain is evidence of the manifestation of heterosis.

Thus, the high adaptive and productive potential of the Hereford breed and its crosses with the Simmental breed allows using them for sustainable development of beef cattle breeding in the conditions of Siberia.

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