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Effect of Polyunsaturated Fatty Acids on Metabolic and Energy Levels in Yakutian Horses

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ABSTRACT
The article presents the results of research on the influence of winter grazing on the aftergrass of natural and seeded grass and linseed cake feeding on metabolism and energy indices in Yakutian horses in winter. It was found that the aftergrass of seeded grass (winter-green oat mass) was characterized by a high content of nutrients and energy-intensive substances. Reliable differences were found out for dry matter 63.7 ± 0.13 % and for protein - 9.0 ± 0.14 % (P ≥ 0.95). The carotene content of winter-green oats is 104.6 % higher than that of natural grass (28.4 ± 0.76 %) and amounted to 133.0 ± 0.44 % (P ≥ 0.999). The largest amounts of polyunsaturated fatty acids have been identified. Thus, the sum of polyunsaturated fatty acids in the aftergrass of seeded grass (winter-green oat mass) was 40.7%, which is 25.06% higher than the sum of fatty acids of natural grass (15.65 ± 0.18%). The high content of polyunsaturated fatty acids in winter-green oat mass contributed to higher digestion of dry (66.5%) and organic (66.1%) substance, raw protein (70.6%), raw fiber (65.4%), crude fat (51.5%) and nitrogen-free extractive substances (66.7%) than in the case of winter gazing horses on natural grass and, correspondingly, higher usege of metabolizable energy per head per day (145.4 ± 3.32 MJ) and per 100 kg of live weight (36.53 ± 2.48 MJ). The inclusion of linseed cake in the horse's winter diet had a positive effect on the digestibility of feed in the horse's body, and also had a positive effect on metabolizable energy. Reliably high digestibility rates for horses in the experimental group were recorded for raw protein for 3.34% (70.85 ± 0.19%) (P ≥ 0.99), for raw fat by 14.3% (68.59 ± 0.64%) and for nitrogen-free extractive substances by 3.09% (77.71 ± 1.13%) (P ≥ 0.999). The high digestibility of basic nutrients resulted in a high metabolizable energy content of 1 kg of dry matter when included in a linseed cake diet (10.1 MJ) than in a dry fodder-oat diet (9.5 MJ), (P ≥ 0.95). The results obtained by us testify to the necessity of wide application of seeded grass at winter grazing and inclusion of linseed cake as a source of polyunsaturated fatty acids in winter for Yakutian hosres.

Keywords: The Republic of Sakha (Yakutia), Yakutian horses; aftergrass of natural grass; aftergrass of seeded grass; linseed cake; dry fodder-oat diet; coefficient of digestibility of feed nutrients; metabolizable energy; polyunsaturated fatty acids.

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INTRODUCTION

Horse-breeding is one of the main animal husbandry sectors, the basis of the Sakha people's way of life and economy. The Republic of Sakha (Yakutia) is one of the regions of Russia, where meat droving horse-breeding has long been developed. The combination of different abiotic factors in one region has affected the nature of ecological, physiological and biochemical aspects of adaptation of plants to the extreme climate of Yakutia. K.A. Petrov (2014), G.V. Filippova (2003), A.A. Grigorieva, G.E. Mironova (2015) note that local plants have a high content of nutrients and biologically active substances, significantly higher than their level in plants of other regions, which is very important for northern agriculture [1-3]. The main feed base for herbivores, including Yakutian horses, are meadow phytocoenoses, represented by four main groups: alas, alluvial, bottomland and upland. Alas meadows occupy the largest share of areas - up to 50% of all meadows used as hay and pasture lands. They are of good quality, with high-protein Pucciriella and Alopecums cereals prevailing, but are characterized by low yields of 4 to 13 c/ha, caused by high dependence on precipitation of specific years. Alluvial meadows composed of various Hordeum, Alopecurus, Arctophila etc. cereals, sedge and horsetail have smaller areas of about 30 %, but due to high yield from 15 to 20 c/ha give more than one third of forage lands in the republic [1].

In Yakutia, pasture areas are used haphazardly: cattle and horses graze on the same areas. Aftermath grazing of hayfields close to settlements in autumn by cattle does not leave stocks for horses for a long, winter grazing period. In normal years, grass yields are only 1.8-3.0 c/ha, and in dry years even less. There is a chronic shortage of winter grazing pastures in the breeding zones of herd horses. The availability of horses' pastures reaches 55-60% of the demand for them. Forced systematic overloading of natural stocking and grazing pastures leads to their degradation [4]. Thus, the maintenance of horses on low-productive pastures forms deficiency of energy and the basic nutrients in an organism that is the main reason of low industrial results of horse breeding, beginning with loss of fatness and weight conditions of horses and finishing with decrease in indicators of reproduction of the population.

In order to eliminate these factors, which hinder further increase of productivity and improvement of the quality of horse breeding production, along with strengthening the feed base, it is necessary to enrich the winter diet of horses with seeded winter-green fodder. Winter green fodder consists of those plants, which are partially or completely preserved under the snow in green form.

Cold adaptation to low temperature stress leads to the accumulation in plants of the most energy-intensive compounds of important plastic substrates of bioactive substances - sugars, proteins, antioxidants and carotenoids, which perform energy and protective functions, but also a significant number of total lipids and medium-chain polyunsaturated fatty acids. Thus, the absolute content of total lipids increases 2-fold in autumn in seeded oats and 1.5-fold in natural grass as compared with summer indicators [5, 6]. Palmitic (C16:0) acid prevailed in the fatty acid spectrum of saturated fatty acids of seeded oat leaves, the content of which varied from 15.3% in summer to 18.0% in autumn. The high level of unsaturated fatty acids in seeded oats is mainly caused by two acids - linoleic C18:2 (n-6) and ϵ-linoleic C18:3 (n-3). At the same time, the largest amount of linoleic acid C18:2 (n-6) was observed in autumn - 10.9%, which is 7.7% higher than in summer. The unsaturated ratio was 4.44 in summer and 3.26 in autumn. Studies of the fatty acid composition of natural cereal and horsetail grass found that during the transition to the period of cold hardening the content of palmitic acid (C16:0) decreased by 29.3 % compared to summer. The relative content of saturated fatty acids in the summer period was 34.7 % and decreased to 30.2 % in autumn. At the same time the level of linoleic acid C18:3 (n-3) fell by 16% [1].

Based on the results of studies conducted by K.A. Petrov et al. (2010, 2011, 2012) it was noted that a significant content of unsaturated fatty acids and carotenoids in the tissues of autumn vegetation and winter green plants play a key role in regulating the resistance of herbivorous animals, including the Yakutian horse to long-term low temperature stress [7-9]. It is known that cooling of animals adapted to cold causes an increase in free fatty acids content in their tissues [10]. Studies of the fatty acid composition of lipids in the fatty tissue of Yakutian horse found that the content of linoleic C18:2 (n-6) and ϵ-linoleic C18:3 (n-3) acids was 6.1 ± 0.2% and 18.8 ± 0.5% of the total fatty acids. Such composition of polyene fatty acids in foal fat tissues indicates active intake of linoleic and linolenic acids together with feed from autumnal vegetative and winter green plants [11]. The given results are consistent with the data of foreign authors. In Dewhursta R.J andet. (2006) the fatty acid composition of the main feed was considered and the possibilities for increasing the content of mono- and polyunsaturated fatty acids in milk of dairy cows were revealed [12-15].

Polyunsaturated fatty acids are not synthesized by the animal's body and in case of insufficient quantity of these acids the synthesis of higher derivatives of linoleic acid, metabolism, reproductive functions of the animal are disturbed [9]. Fodder with a high content of polyunsaturated fatty acids quickly activate and normalize metabolic processes of animals, being a source of part of energy necessary for metabolism in the body [16]. With this diet there is an additional supply of fat-soluble vitamins (A, D, E and K), usually in short supply [17].

In this regard, when breeding herd horses in Yakutia, it is very relevant to create and use seeded grazing lands, and to include highly effective secondary fodder resources saturated with polyene fatty acids, such as linseed cake into the composition of fodder. This has given rise to research and development activities.

There are enough studies, including foreign ones, where it is indicated that the set of certain fodder can significantly regulate lipid and fatty acid composition of diets and change their effect on productivity and metabolism in monogastric animals [19-20].

The researchers found that linseed cake has a significant amount of linoleic and α-linolenic acids in the composition, also B vitamins, pantothenic, folic acids, biotin, α-tocopherol (vitamin E), trace elements [18-22]. Linseed cake has a balanced amino acid composition of protein part and a low concentration of raw fiber, also has a high energy value: 1 kg of cake contains 1.27 k.u. units. 13.73 MJ (as in 1.3-1.4 kg of oats) 287 g of digestible protein.

Earlier we studied the efficiency of using oat crops as winter-green grazing pastures for Yakutian horses [23-26]. At the same time, there are practically no studies of the influence of fatty acid composition of seeded and natural aftergrass of Central Yakutia grass on the peculiarities of metabolism of Yakutian horses in winter period.

In order to confirm the assumption that lipids, being an energy source, play a special role in regulation of Yakutian horse resistance to hypothermia in extreme conditions of Yakutia and taking into account the fact that recently many farms prefer to use secondary raw material resources instead of mixed fodder and grain forage in feeding animals, we have carried out the second scientific and economic experience on studying the influence of feeding linseed cake, a source of irreplaceable fatty acids on metabolism and energy in Yakutian horses.

The objective of the study is to study the influence of polyunsaturated fatty acids on metabolism and energy indices of Yakutian horses in winter when they are grazing natural and seeded grass.

RESEARCH MATERIAL AND METHODOLOGY

The first scientific and economic experience in studying the impact of winter grazing on natural and seeded grassesaftergrass on the metabolism and energy of Yakutian horses in the winter period was carried out in 2015 at the Krasnaya Zvezda experimental farm of the Megino-Kangalassky ulus. Oats were sown according to the generally accepted technology of annual crops sowing in specially constructed enclosures of 1.5 hectares and areas under natural grass were taken for control.

The second scientific and economic experience in studying the efficiency of the diet with linseed cake on the metabolism and energy of Yakutian horses in the winter period was carried out in 2018 at the physiological yard of the M.G. Safronov Yakut Scientific Research Institute of Agriculture.

For both experiments, a group of 3 merino heads was formed on the principle of pairs of analogues. The difference between the analogs in live weight, age did not exceed 10%.

Schemes of experiments and ration of horses are presented in Tables 1 and 2. The ration corresponds to the norm of feeding of Yakutian horses, in particular, merinoes with live weight of ±400 kg without labour load (Kalashnikov, 2003, Abramov, 1977).

For carrying out physiological experiment the animals were placed in special pens for feces collection and feed accounting. Sampling of fodder and feces was carried out by methods of scientific research in animal breeding (G.E. Usakov, 2014).

The yield of calf fodder was determined by the methods of field experience (V.M. Kuznetsov, 2006).

To determine the consumption and digestibility of pasture fodder the fecal index method by E.U. Krempton, L.E. Harris (1972) was used. This method is mainly used to determine the digestibility of pasture grass. Feed consumption and fecal excretion were quantitatively determined. Using this method, only feces were analyzed, as a direct correlation between the digestibility of feed nutrients and the nitrogen content in animal feces was established [27].

The feed exchange energy was determined by the regression equation given by the staff of the All-Union Research Institute of Horse Breeding (A.N. Kosharov, S.T. Ugadchikov, V.G. Memedeykin, 1983).

Biochemical analyses were carried out in the laboratory of agricultural products processing and biochemical analysis with the NIR SCANNER model 4250 near infrared spectroscopy analyzer manufactured in the USA.

Determination of fatty acids composition of fodder grass lipids was carried out in the Federal State Budgetary Institution of Science Federal Research Center of Nutritive Systems V.M. Gorbatov. Extraction of lipids from samples was carried out by chloroform/methanol extraction according to the Folch method, in which a mixture of chloroform-methanol (2:1) was used at the rate of 20 parts of the extracting mixture per one part of tissue. The method allows to extract 90-95% of all cell lipids (N.M.Orel, 2007). The purity of isolated lipids was checked by thin layer chromatography method - analytical method of fast separation of low molecular weight substances. Determination of the composition of fatty acids was carried out on a gas chromatograph "Hewlett Packard" HP 6890 produced in the USA. The principle of operation of the chromatograph is based on separation of mixtures of substances and their subsequent detection [28-29].

The main digital data obtained in the research was processed by biometric method using Microsoft Excel computer program.

RESEARCH RESULTS

Frozen by natural cold green mass of seeded oats (Avena sativa L.) was in the phase of outlet into the tube at the time of grazing, the aftergrass of natural grass was in the phase of thawing, with overripe coarsened plants in small amounts, i.e. all species of plants passed approximately the same cycle of vegetation. Oat crops had light green color with ragged plant tips, natural grass aftergrass had pale green color preserved only at the root of plants.

Table 3 shows that the yield of winter green seeded oats was 161.1 ± 0.11 c/ha, which is 31.5 times higher than the yield of natural grass aftergrass 5.1 ± 0.09 c/ha ($P \geq 0.999$). Reliable differences were found in dry matter of 63.7 ± 0.13 %, 21.4 % higher than the content of natural grass in aftergrass (42.3 ± 0.53 %), protein - 6.5 %, respectively ($P \geq 0.95$). The carotene content of winter green oat mass was 133.0 ± 0.44 %, 104.6 % higher than that of natural grass ($P \geq 0.999$). The interrelationship between carotene and fat is that carotene, being a fat-soluble compound, is present where the fat content is higher. The benefits of seeded oats for horses are determined by the fact that summer seeded plants that are intended to be preserved by natural cold are long "prepared" for this. In autumn, the cells of these plants are gradually rearranged biochemical processes and chemical composition. Monosaccharides accumulate in the plants and the number of polysaccharides is reduced. As moisture is lost in the plants, the concentration of cell juice increases. As the temperature drops further, the plants fall into anabiosis, and the nutrients seem to be fixed at the level of fresh, green plants. Plants conserved in natural cold have a natural appearance and look as if they are alive. We assume that due to gradual adaptation to the cold, plants retain their natural biological natural "native" ratios and nutrient bonds. Here, unsaturated fatty acids and plant carotenoids seem to play a major role [1].

We assume that the presence of 4.7 times more carotene in the winter-green mass of oats than in the natural grass contributed to the long-term preservation of the quantity and quality of basic nutrients and their relationships with each other in the biologically natural, native state.

In the process of cold hardening, in addition to changes in energy metabolism and synthesis of stress proteins, there is an increase in phospholipid content and unsaturated fatty acid residues [30-31]. It was found that adaptation of plants to prolonged low temperature stress is closely connected with the main sources of energy - lipids and polyene fatty acids, which play the main role in the formation of high nutritive value of frozen natural cold vegetation of the cryolithosone [32-33].

Table 4 shows the fatty acid composition of winter-green oats compared to the aftergrass of natural grasses when Yakutian horses are grazed.

Unsaturated fatty acids dominate in the lipid composition of the studied seeded grass, the total content of which was 56,59 ± 0,97 % in the winter-green mass of oats, in the aftergrass of natural grass is 25,44 % less (31,15 %) ($P \geq 0,95$).

In winter-green oats, the largest amounts of polyunsaturated fatty acids were identified. Thus, the sum of polyunsaturated fatty acids was 40.7%, which is 25.06% higher than the sum of fatty acids of natural grass (15.65±0.18%) ($P \geq 0.99$).

The content of linoleic (C18:2 w6) fatty acid, which plays an important role in metabolic processes, in winter green oat lipids is 7.64% higher than in natural grass (11.2±0.17) and amounted to 18.84 ± 0.32% ($P \geq 0.95$).

The low content of γ- and α- linolenic acids in the studied plants can be explained by the specifics of fatty acids metabolism, which is expressed in the reduced ability to form these acids.

In terms of the content of basic polyunsaturated fatty acids, the aftergrass of natural grass is inferior to the winter-green mass of oats. As noted above, the accumulation of more polyunsaturated fatty acids in winter-green oats can occur to protect plants from the effects of low temperatures.

Many authors testify to the influence of polyene fatty acids resistance to cold. In researches of H.R. Shimshilashvili and others (2007) it is shown that genes DesA and DesC participate in protection of organism from influence of low temperature. Expression in potato transformers and native (DesA and DesC) and hybrid (DesA-LicBM2 and DesC-LicBM2) genes of A12-desaturase stimulates membrane lipid biosynthesis and increases the level of unsaturated fatty acids, which may lead to increased cold resistance [34].

The increase of unsaturated fatty acids in membrane lipids leads to increased resistance to cold. However, increasing the level of unsaturated fatty acids in membrane lipids is not the only mechanism of response to cold [35].

Despite a number of drawbacks pointed out by many researchers, nutrient digestibility remains the main indicator for assessing the nutritional value of feeds at present.

Table 5 shows the digestibility coefficients of nutrients of the studied fodder.

The high content of polyunsaturated fatty acids in winter-green oats apparently contributed to higher digestibility of dry (66.5%) and organic (66.1%) substance, raw protein (70.6%), raw fiber (65.4%), raw fat (51.5%) and nitrogen-free extractive substances (66.7%) than in the case of herding horses on the aftergrass of natural grass and, accordingly, a higher use of exchange energy of 1 kg of dry matter 9.9 MJ than in the aftergrass of natural grass - 8.3 MJ. (Table 5). Such high digestibility of nutrients is explained by the balanced nutrient balance of winter-green oats.

A.J. McAfee, at all (2011), P. Willace (2007) found that green grasses from natural pastures, as well as specially cultivated crops for green fodder, are well digested, easy to absorb and have dietary properties, while young green grasses have the highest biological value than concentrated feeds. [36-37]. V.M. Kuznetsov (2006) suggested that fat can slow down the rate of chyme through the digestive tract and thus increase digestion and absorption time [38]. A.A. Aliev (1987) has noticed that the degree of unsaturated and the length of the fatty acids carbon chain influences the potential of micelles formation and therefore they are digested more effectively than saturated ones and thus increase the overall digestibility [39].

We assume that the presence of a significant amount of carotene in the winter-green mass of oats, compared to the aftergrass of natural grass, contributed to the accumulation of more energy-intensive compounds, important plastic substrates of bioactive substances - lipids, total fatty acids and antioxidants (polyene fatty acids, vitamins, etc.), which significantly increase the nutritive value of autumn-vegetating and winter-green herbaceous plants, which contributed to good digestibility of these elements in the body of Yakutian horses in winter.

Researches have established that consumption of dry matter of fodder at grazing of horses on winter-green mass of oats is by 31,3 % authentically more than at grazing on aftergrass of natural grass and has made 14,7 ± 0,30 kg ($P \geq 0,99$). The differences are also shown in the metabolizable energy content of 1 kg of dry matter of the fodder consumed. For example, the metabolizable energy content of winter green oats aftergrass is 16.2 percent higher (9.9 ± 0.04 MJ) than in natural grass (8.3 ± 0.23 MJ), the difference is statistically significant ($P \geq 0.95$).

The daily metabolizable energyof consumption per head was -83.83 ± 1.98 MJ in natural grass and 42.3 percent more in winter green oats (145.4 ± 3.32 MJ) ($P \geq 0.99$). At the same time, the metabolizable energy provision per 100 kg of live weight reached 36.53 ± 2.48 MJ, which is 37.6 percent more than with natural grass (22.78 ± 1.06 MJ) ($P \geq 0.95$).

Thus, the winter-green mass of oats in grazing of Yakutian horses in the second half of winter as the only feed fully meets the needs of horses in metabolizable energy.

Thus, the winter-green mass of oats, when grazing Yakutian horses in the second half of winter as the only fodder fully meets the needs of horses in metabolizable energy.

To confirm our results that lipids, being a source of energy, play a special role in regulation of Yakut horse resistance to hypothermia in extreme conditions of Yakutia and taking into account the fact that linseed cake is a source of significant amounts of polyene fatty acids, we studied the influence of linseed cake feeding on metabolism and energy indices of Yakutian horses during winter period. Researches of L.I. Podobed (2019) have established that linseed cake, as a rule, contains much more omega-3 and omega-6 fatty acids than other cakes. Our studies have shown that linseed cake contains 28.8% α-linolenic acid and 29.3% γ-linolenic acid of the total fatty acids. It should be noted that in oats the amount of α- and γ-linolenic acids is much lower than in linseed cake (Table 7).

Researches of L.I. Podobed (2019) have established that the linseed cake, unlike other oil cakes on a ratio ω-3 to ω-6 has a more correct ratio and makes 1:1,12, whereas the sunflower oil cake has 1:572 [18]. According to our data, the ratio ω-3 to ω-6 is 1:2 in linseed cake, which is more consistent with the correct ratio ω-3 to ω-6 (Table 7).

Oats in terms of fatty acids can not be compared with oil cakes, because it is a product rich in fiber, vitamins of group B, micro-macronutrients, and fat, although compared with oil cakes, its fat content is slightly lower.

Table 8 shows the chemical composition of hay, oats and linseed cake consumed by the animals in comparison.

Analysis of the chemical composition of linseed cake shows its high forage qualities. Thus, the content of raw protein in linseed cake was 23.95 ± 0.80 %, which is 10.35 % more than its content in hay and 3.52 % more than in oats ($P \geq 0.95$). Fiber content was 41.70 ± 0.21%, which is 27.64% higher in hay than in oats and 33.95% higher than in linseed cake ($P \geq 0.95$). Linseed cake has a high fat content of 9.04 ± 0.68 %, which is 7.42 % higher and 6.09 % higher than in hay and oats ($P \geq 0.95$). There is a reliable advantage of 51.94 ± 0.44% in the content of nitrogen-free extractive substances in oats, which is 17.72% and 7.54% higher than in hay and linseed cake ($P \geq 0.95$). No reliable differences were found for calcium and phosphorus.

Daily supplementation with linseed cake as part of horse diet in the second period of experience had a positive impact on digestibility of nutrients in the diet (Table 9).

The intensity of use of nutrients in the diet of Yakutian horses is evidenced by the data on digestibility coefficients

of feed nutrients. The data of Table 8 show that the digestibility of the main nutrients in horses in the second period of experience, which received as part of the linseed cake diet is higher than in the first period. Reliably high digestibility coefficients for horses in the second period were noted for raw protein - by 3,34 % (70,85 ± 0,19 %), for raw fat - by 14,3 % (68,59±0,64 %) and for nitrogen-free extractive substances - by 3,09 % (77,71±1,13 %) ($P \geq 0{,}999$).
Table 10 shows data on energy value of fodder and metabolizable energy consumption of Yakutian horses during winter period.

Our studies have established reliable differences in the metabolizable energy content of 1 kg of dry matter of the consumed feed. Thus, the metabolizable energy content of the second period of experience, when horses were given 5.78% more (10.06 ± 0.22 MJ) in the main linseed cake diet than in the first period when the main diet consisted of hay and oats (9.51 ± 0.27 MJ), the difference is statistically significant ($P \geq 0.95$). The metabolizable energy consumption per head per day for horses in the second period was 7.15 percent higher (129.06 ± 1.41 MJ) and 119.82 ± 2.18 MJ in the first period ($P \geq 0.95$). The metabolizable energy provision per 100 kg of live weight for horses in the second period was 32.0 ± 0.67 MJ, 6.75 percent more than in the first period (29.84 ± 0.18 MJ) ($P \geq 0.95$).

CONCLUSIONS

1. The results allow us to conclude that the root frozen winter green mass of oats under stressful cold hardening synthesize more energy-intensive substances. Reliable differences were found in dry matter 63.7 ± 0.13%, which is 21.4% higher than the content in the aftergrass of natural grass (42.3 ± 0.53%), protein - by 6.5% respectively ($P \geq 0.95$). The carotene content of winter green oats was 133.0 ± 0.44 %, which is 104.6 % higher than that of natural grass ($P \geq 0.999$). The largest amounts of polyunsaturated fatty acids were identified in the winter-green mass of oats. Thus, the sum of polyunsaturated fatty acids was 40.7%, which is 25.06% higher than the sum of fatty acids in natural grass (15.65 ± 0.18%). The content of linoleic (C18:2 w6) fatty acid in winter-green oat lipids was 18.8%, which is 7.64% higher than in natural green aftergrass (11.2±0.17). The high content of polyunsaturated fatty acids in winter-green oats contributed to higher digestion of dry (66.5%) and organic (66.1%) substance, raw protein (70.6%), raw fiber (65.4%), crude fat (51.5 percent) and nitrogen-free extractive substances (66.7 percent) than in the case of herding horses on natural grass and, correspondingly, higher metabolizable energy per head per day (145.4 ± 3.32 MJ) and per 100 kg of live weight (36.53 ± 2.48 MJ).

2. The inclusion of linseed cake in the winter diet of horses had a positive impact on the digestibility of fodder in the horse body, in addition, balanced feeding in accordance with the norms of feeding the Yakutian horses had a positive impact on metabolizable energy. Reliably high digestibility coefficients in horses with inclusion of linseed cake in their diet were marked on raw protein - by 3,34 % (70,85 ± 0,19 %) ($P \geq 0{,}99$), on raw fat - by 14,3 % (68,59 ± 0,64 %) and on nitrogen-free extractive substances - by 3,09 % (77,71±1,13 %) ($P \geq 0{,}999$). The high digestibility of basic nutrients resulted in a high metabolizable energy content of 1 kg of dry matter when included in a linseed cake diet (10.1 MJ), compared with a dry fodder-oat diet (9.5 MJ), ($P \geq 0.95$).

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ANNEX 1.

Table 1: Scheme of experiments on Yakutian horses to study the nutrition and digestibility of natural and seeded grass

Month	Factor under study	Horses maintenance	Horses age	Length of periods (days)	
				preparation	accountable
February	Aftergrass of seeded grass (winter-green oat mass)	Pastureland in the enclosure	10 years	5	6
February	Aftergrass of natural grass	Pastureland in the enclosure	10 years	5	6

Table 2: Scheme of experiments on Yakutian horses on study of nutrition and digestibility of fodder with linseed cake

Month	Factor under study	Horses maintenance	Horses age	Length of periods (days)	
				preparation	
February	Main diet: 13 kg of dry fodder, 1.5 kg of oats	In enclosure	10-11 years	5	6

February	Main diet: 12 kg of dry fodder, 0.5 kg of oats + 2 kg of linseed cake	In enclosure	10-11 years	5	6

Table 3: Yields and chemical composition of seeded oats and oats of natural grass in enclosures for experiments

Indicators	Range fodder	
	Aftergrass of natural grass	Aftergrass of seeded grass (winter-green oat mass)
Yields, c/ha	5.1±0.09	161.1±0.11***
Nutrient content in absolutely dry matter, %		
dry matter	42.3±0.53	63.7±0.13*
protein	9.0±0.14	15.5±0.77*
fat	1.5±0.08	2.2±0.18
cellulose	35.4±0.13	35.5±0.04
nitrogen-free extractive substances	49.1±0.66	38.7±0.43
ashes	4.9±0.34	8.1±0.23
phosphorus	0.20±0.07	0.26±0.04
calcium	2.34±0.76	1.18±0.35
Carotene, mg/kg	28.4±0.76	133.0±0.44***

*P ≥ 0.95; ***P ≥ 0.999

Table 4: Fat-acid composition of winter grazing fodders, %

Indocator	Aftergrass of natural grass	Aftergrass of seeded grass (winter-green oat mass)
Saturated fatty acids		
MyristicAcidC14:0	0.3±0.01	2.23±1.10*
Palmitic Acid C16:0	14.0±0.07*	6.41±0.13
Stearic Acid C18:0	11.7±0.03**	1.43±0.12
Sum of the saturated fatty acids	32.5±0.17	28.42±0.40
Monounsaturated fatty acids		
OleicAcidC18:1n9c	11.8±0,04*	6,.9±0.37
Erucic Acid C22:1n9t	-	6.69±0.41
Sum of onounsaturated fatty acids	15.5±0.17	15.88±0.18
Polyunsaturated fatty acids		
Линолевая LinoleicAcidC18:2 w6	11.2±0.17	18.84±0.32*
γ-linolenic cis-6,9,12-octadecatrienoic C18:3 w6	2.75±0.03	3.68±0.43
α- linolenic cis-9,12,15-octadecatrienoic C18:3 w3	0.44±0.03	0.82±0.19
Sum of polyunsaturated fatty acids	15.65±0.18	40.71±0.11**
Sum of unsaturated fatty acids	31.15 ± 0.25	56.59 ± 0.97*

*P ≥ 0.95; **P ≥ 0.99

Table 5: Nutrient digestibility coefficients of frozen green mass of oats and oatmeal of natural grass at winter glaring of horses (n=3), %

Indicator	Fodder	
	Aftergrass of natural grass	Aftergrass of seeded grass (winter-green oat mass)
organic matter	54.2±0.64***	66.1±2.01***
dry matter	56.02±0.98**	66.5±0.23**
raw protein	52.3±2.02***	70.6±0.31***
raw fiber	43.5±1.05***	65.4±1.03***
raw fat	38.2±2.0***	51.5±1.33***
nitrogen-free extractive substances	55.0±2.00**	66.7±0.65**

**P≥0,99; ***P≥0,999;

Table 6: Energy value of feeds and energy supply of horses during winter glaring

Fodder	Fodder consumption, kg		Metabolic energy in 1 kg dry matter, MJ	Consumption of metabolic energy, MJ	
	Of natural mass	Of dry matter		Per head per day	Per 100 kg of live mass
Aftergrass of natural grass	12.31 ± 0.15	10.1 ± 0.35	8.3 ± 0.23	83.83 ± 1.98	22.78 ± 1.06
Aftergrass of seeded grass (winter-green oat mass)	19.03 ± 1.08*	14.7 ± 0.30**	9.9 ± 0.04*	145.4 ± 3.32**	36.53 ± 2.48*

* P ≥ 0.95; ** P ≥ 0.99

Table 7: Fatty acid composition of linseed cake and oats, %

	Fat g/100g	Oleic (ω-9), %	Linolic (ω-6), %	α- linolenic (ω3), %	γ- linolenic (ω6), %
Linseed cake	9.04±0.83	23.31±0.49	33.18±3.11	28.85±2.99***	29.31±0.49***
Oats	7.10±0.57	34.80±0.38	23.31±0.19	1,04±0.48	2.15±0.82

*** P>0.95

Table 8: Chemical composition of dry fodder and linseed cake in experiment, %

Indicator	Dry fodder	Oats	Linseed cake
Water	4.58 ± 0.20	4.39 ± 0.13	13.59± 0.73
In percent per a/s matter, %			
Raw protein	13.00 ± 0.78	20.43±0.35	23.95±0.80*
Raw fat	1.62 ± 0.09	2.95±0.22	9.04±0.68*
Raw fiber	41.70 ± 0.21*	14.06±0.11	7.75±1.17
Nitrogen-free extractive substances	34.22 ± 1.26	51.94±0.44*	44.40±1.24
Raw ash	4.98 ± 0.09	2.87±0.05	5.99±0.52
Phosphorus, g	0.20±0.01	0.32±9.42	0.79 ± 0.27
Calcium, g	0.54±0.04	0.60±1.67	0.33 ± 0.75

*P ≥ 0.95

Table 9: Nutrient digestibility coefficients of the diet, %

Periods	Indicator					
	Of dry matter	Of organic matter	Of raw protein	Of raw fat	Of raw fiber	Of nitrogen-free extractive substances
First	60.94±1.12	58.24±2.41	67.51±0.17	54.29±0.98	39.30±0.81	74.62±1.04
Second	60.18±0.98	63.21±1.87	70.85±0.19**	68.59±0.64***	39.85±0.67	77.71±1.13***

**P ≥ 0.99; *** P>0.999

Table 10: Energy value of fodders and energy supply of horses when feeding linseed cake

Periods	Fodder consumption, kg		Metabolic energy in 1 kg dry matter, MJ	Consumption of metabolic energy, MJ	
	Of natural mass	Of dry matter		Per head per day	Per 100 kg of live mass
First	15.35 ± 0.15	12.6 ± 0.11	9.51 ± 0.27	119.82 ± 2.18	29.84 ± 0.18
Second	16.61 ± 1.08	12.83 ± 0.09	10.06± 0.22*	129.06 ± 1.41*	32.0 ± 0.67*

* P ≥ 0.95;