

## Energy and economic efficiency of corn silage production with flat grain of soy bean on reclaimed lands of upper volga

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### ABSTRACT

This study presents the results of ensiling technology of the aboveground mass of corn both in pure form and with flat grain of soybeans or its green in order to provide canned fodder with digestible protein up to the zootechnical norm for high-intensity livestock farms. The study was carried out on the reclaimed lands of the Non-Chernozem zone on the basis of the livestock farm OJSC "Agrofirm Dmitrova Gora" of the Konakovsky district of the Tver region. They used the soybean variety of the northern ecotype with an indeterminate growth type - Okskaya. It was found that with flat soybean grain increase in silage by 1%, the yield of digestible protein elevates by 3.7% on average, and with the ratio of soybeans and corn by 8:92%, a complete supply of 1 feed unit with protein (106.5 g) is recorded. The yield of metabolic energy in the variant of experiment by 8:92%, where the feed unit reached the zootechnical norm in terms of protein supply, was practically the same in comparison with the preparation of silage from the aboveground mass of soybeans and corn in the ratio of 15:85% and amounted to 145.42 GJ ha<sup>-1</sup> and 145.89 GJ ha<sup>-1</sup> respectively.

**Key words:** Corn-soybean silage, Flat grain, Digestible protein, Nutritional value of feed, Protein supplements, Energy assessment of feed.  
**Article type:** Research Article.

### INTRODUCTION

Provision of animal husbandry with fodder protein in our country, especially in a modern economy, is the most important theoretical and practical task. This problem is being regarded more and more by those farms whose soil and climatic conditions allow to produce feed independently in one degree or another. The issues of the nutritional value of the produced feed remain relevant within the framework of justified zootechnical requirements. It is known that currently silage occupies a significant place in the feed ration. For example, its share can be from 30 - 50% in the feed balance of dairy cattle. In Russia, the main source of silage fodder production is corn. When organizing the feeding of highly productive animals and the planned milk yield of 8000 kg of milk per year, the requirements per cow will be as follows: fodder units and digestible protein will be 72.8 centners (100 kg) and 859 kg respectively. So that, the provision of one feed unit with digestible protein should be 110 g (Kobozeva *et al.* 2015). However, corn silage, containing 50 - 65 g of digestible protein on average, does not meet the requirements of the zootechnical norm. Besides, corn protein is deficient in amino acids such as lysine and tryptophan. It is estimated that the deficiency of digestible protein in the feed ration of ruminants can be 25 - 30% of the norm. This leads, first of all, to the overconsumption of feed by 1.4 - 1.6 times, the increase in labor costs, to health deterioration, animal productivity reduction and, thus, to production increase up to 60 - 70% (Legeza 2001). It is possible to increase the protein value of feed significantly through the joint silage of corn and soybeans. It is most expedient to grow the soybean varieties of the northern ecotype in the Non-Black Earth Zone, the grain of which contains 275 - 292 g of digestible protein per 1 feed unit (Shevchenko *et al.* 2018).

With the development of an adaptive cultivation technology for these varieties, it became possible to use the above-ground mass of soybeans, as well as flat soybeans as a high-protein component for silage with corn in the Non-Black Earth Zone for the first time. Flat grain and preservation of combined silage is a relatively new and promising method of forage production. This improves the availability of starch, which loses its original structure and is easily exposed to amylase, since whole grains of soybeans are almost not digested (Legeza 2001). The total nutritional value of the feed and its digestibility are increased with ensiling of flat soybean grain with the aboveground mass of corn (Shevchenko et al. 2018). There are many reports about plant production studies around the world (Vladimirovna Demina et al. 2020; Omidipour et al. 2021; Abolhasani et al. 2021).

The aim of the study was to develop a technology for the production of high-quality corn-soybean silage to increase the yield of livestock products in the farms of the Non-Chernozem zone. To solve this goal, it is necessary to substantiate and implement the technology of soybean crushing as a protein supplement in the preparation of combined corn-soybean silage, as well as to conduct an economic and energy assessment of such feed.

## MATERIALS AND METHODS

As an object of the study, the indeterminate soybean variety Okskaya was selected, which successfully ripens at the latitude of 56° with the sum of active temperatures 1600 - 1800 °C (Shevchenko & Soloviev 2006; Kobozeva et al. 2015). As a maize component in terms of biological and morphological parameters, the early ripening hybrid of maize PR 39Bx29 is most adapted to the conditions of the Upper Volga region. The experiments were carried out in the field grain-tilled crop rotation at the test site of OJSC "Agrofirm Dmitrova Gora" of the Konakovsky district of the Tver region in 2012 - 2016. Soybeans were harvested at the end of the waxy phase - the beginning of the full ripeness of grain. To flatten wet grain, the Murska-700S roller conditioner was used, with the grain capacity of 10 ton h<sup>-1</sup>. When laying silage with corn, they used the preservative Biotrof with an application rate of 3 - 4 L ton<sup>-1</sup>. Corn was harvested at the end of the waxy - the beginning of full ripeness of the grain, leaving stubble just below the level of the first ear.

The influence of flat soybeans on the content of digestible protein in silage was studied in the mass ratio of 1 to 10% to the corn component. The calculation of economic efficiency was carried out on the basis of technological maps for each ratio of silage components. The assessment of the energy efficiency of corn-soybean silage was carried out according to the method by Posypanov & Dolgodvorov (1995).

## RESULTS AND ITS DISCUSSION

After the studies, it was found that with the legume component share increase in the form of crushed soybean grain in the silage by 1%, the collection of feed units per hectare (by 1.1% on average) and the yield of digestible protein (by 3.7% on average) is increased. The provision of 1 feed unit for digestible protein, corresponding to the zootechnical norm, was achieved with the ratio of components 8:92% and amounted to 106.5 g of digestible protein. At that, such a feed unit contained 64.0 g of essential amino acids, including 8.2 g of critical ones, which is almost two times higher than that of the control variant (34.8 and 4.7 g, respectively) (Table 1). We have calculated the conditional yield of livestock products when 1 feed unit contains 106.5 g of digestible protein. The conditional yield of pork in live weight was 16.51 c ha<sup>-1</sup> (+ 4.23 c ha<sup>-1</sup> to control), beef - 11.80 c ha<sup>-1</sup> (+3.03 c ha<sup>-1</sup> to control), milk - 105.09 c ha<sup>-1</sup> (+26.94 c ha<sup>-1</sup> to control). Calculations lead to the conclusion about the high efficiency of joint ensiling of flat soybeans and corn and the use of such feed in pig breeding, as well as in meat and dairy farming.

At present, to calculate the effectiveness of indicators of any agrotechnical method, the most obvious and integral indicator is its assessment in energy equivalent. We have carried out the corresponding calculations (Table 2). The use of flat soybean grain as a legume component in silage with corn does not lead to a significant increase in the total energy consumption per 1 hectare of crops compared to the technology of ensiling of the entire aboveground mass at the end of wax (at the beginning of full ripeness). Net energy income, energy cost, as well as the costs of man-hours per 1 ton of silage have very close values in the optimal treatments (8:92%) and make 110.27 and 112.16 GJ ha<sup>-1</sup>; 2.25 and 2.16 GJ ha<sup>-1</sup>; 1.67 and 1.63 man-hour for 1 ton, respectively. The energy received with the products in all treatments is more than three times the energy expended, which ensures a positive balance of net energy income. The analysis of the economic efficiency of flat soybean grain use as a protein additive in the production of corn silage is presented in Table 3.



**Table 1.** Quality of feed and conditional livestock product yield in case of joint ensiling of flat soybean and corn grain.

Silage ratio: soybeans:corn (%)	Yield from 1 hectare		Content in one feed unit		Conditional output (c ha <sup>-1</sup> )		
	feed units (c)	digestible protein (kg)	digestible protein (g)	essential amino acids (g)	pork	beef	milk
0:100 (control)	100.0	859.6	86.0	34.8	12.28	8.77	78.15
1:99	101.1	896.7	88.7	53.3	12.81	9.15	81.52
2:98	102.1	933.7	91.4	54.9	13.34	9.53	84.88
3:97	103.2	970.8	94.1	56.6	13.87	9.91	88.25
4:96	104.3	1007.8	96.6	58.1	14.4	10.28	91.62
5:95	105.3	1044.9	99.2	59.6	14.93	10.66	94.99
6:94	106.3	1081.9	101.8	61.2	15.46	11.04	98.35
7:93	107.4	1119.0	104.2	62.6	15.99	11.42	101.73
8:92	108.5	1156.0	106.5	64.0	16.51	11.80	105.09
9:91	109.4	1193.0	109.0	65.5	17.04	12.70	108.45
10:90	110.5	1230.0	111.3	66.9	17.57	12.55	111.83

**Table 2.** Energy estimation of silage harvesting from flat grain of soybeans and corn.

Silage ratio soybeans:corn (%)	Digestible protein yield (kg ha <sup>-1</sup> )	Energy consumed (GJ ha <sup>-1</sup> )	Energy received (GJ ha <sup>-1</sup> )	Net energy income (GJ ha <sup>-1</sup> )	Energy cost (GJ ton <sup>-1</sup> ) of silage	Cost of man- hours/ha	Costs of man- hours/ton of silage
0:100 (control)	859.6	32.00	108.14	76.14	2.05	23.66	1.51
1:99	896.7	33.16	112.81	79.65	2.12	24.35	1.56
2:98	933.7	33.51	117.46	83.95	2.14	24.48	1.57
3:97	970.8	33.78	122.13	88.35	2.16	25.01	1.6
4:96	1007.8	34.05	126.78	92.73	2.18	25.14	1.61
5:95	1044.9	34.4	131.45	97.05	2.20	25.27	1.62
6:94	1081.9	34.69	136.1	101.41	2.22	25.41	1.63
7:93	1119.0	34.95	140.77	105.82	2.24	25.55	1.63
8:92	1156.0	35.15	145.42	110.27	2.25	26.07	1.67
9:91	1193.0	35.72	150.07	114.35	2.29	26.18	1.67
10:90	1230.0	36.38	154.74	118.36	2.33	26.31	1.68
Silage from aboveground mass of soybeans and corn*	1159.7	33.73	145.89	112.16	2.16	25.42	1.63

\* Silage from soybeans and corn, harvested at the end of waxy - the beginning of full ripeness with corn mowing height of 40 cm in the proportion of 15% of soybeans and 85% of corn.

**Table 3.** Economic efficiency of silage harvesting from flat grain of soybeans and corn.

Silage ratio soybeans:corn (%)	Digestible protein yield (kg ha <sup>-1</sup> )	Selling price of 1 kg of digested protein	Production cost (rubles ha <sup>-1</sup> )	Production net cost (rubles ha <sup>-1</sup> )	Net income (rubles ha <sup>-1</sup> )	Profitability (%)	Costs (ruble)	
							for 1 feed unit	for 1 kg of digested protein
0:100 (control)	859.6	73.6	63267	46544	16723	35.9	465.4	54.1
1:99	896.7	73.6	65997	46951	19046	40.6	464.4	52.4
2:98	933.7	73.6	68720	47458	21262	44.8	464.8	50.8
3:97	970.8	73.6	71451	48066	23385	48.7	465.8	49.8
4:96	1007.8	73.6	74174	48775	25399	52.1	467.6	48.4
5:95	1044.9	73.6	76905	49543	27362	55.2	470.5	47.4
6:94	1081.9	73.6	79628	50150	29478	58.8	471.8	46.4
7:93	1119.0	73.6	82358	50657	31701	62.6	471.7	45.3
8:92	1156.0	73.6	85082	51164	33918	66.3	471.6	44.3
9:91	1193.0	73.6	87805	51467	36338	70.6	470.4	43.1
10:90	1230.0	73.6	90535	51908	38627	74.4	469.8	42.2

According to the calculated data, it was noted that the cost of production amounted to 63,267 rubles ha<sup>-1</sup> in the control group, where corn was ensiled in pure form and contained 86 g of digestible protein in 1 feed unit, while the net income was 16,723 rubles ha<sup>-1</sup>, and the level of profitability was 35.9%. By the flat grain share increase in the silage mass, the economic indicators upraised, because each additional percentage of the bean component elevated net income by 2,190 rubles (at LSD<sub>05</sub> - 1914 rubles), and the profitability of production elevated by 3.9% (at LSD<sub>05</sub>, 3.7%). Notably, due to the high cost of soybean grain, the cost of 1 centner (100 kg) of feed also

increased slightly. So, with the content of 106.5 g of digestible protein in it, it amounted to 471.8 rubles (+6.4 rubles with  $LSD_{05}$  - 3.05 rubles).

## CONCLUSION

Our research gives a positive conclusion about the possibility and effective use of ensiling both the aboveground mass of soybeans and its flat grain together with the aboveground mass of corn in order to provide the silage feed with digestible protein up to the requirements of the zootechnical norm for high-intensity livestock farms. At the same time, adherence to cultivation technologies, as well as the correct selection of silage components, harvesting in optimal phases, the manufacturability of laying and storing silage provide a high economic efficiency of this technique. Calculations show that the use of flat soybean grain in a combined silage with corn does not lead to a significant increase in the total energy consumption per 1 hectare of crops as compared to the technology of ensiling the entire aboveground mass at the end of the wax (at the beginning of full ripeness of the grain). The yield of metabolic energy in the experiment treatment, where the feed unit reached the zootechnical norm in terms of protein supply, was almost the same in comparison with the preparation of silage from the aboveground mass of soybeans and corn and amounted to: 145.89 GJ ha<sup>-1</sup> in ordinary silage, harvested at the end of the wax (at beginning of full ripeness) of grain and 145.42 GJ ha<sup>-1</sup> when using flat grain in the ratio of 8:92%. The technology of flat soybean grain and its subsequent ensiling and canning with the aboveground mass of corn has a positive effect on the conditional yield of livestock products (the yield of pork in live weight was 16.51 c ha<sup>-1</sup> (+ 4.23 c ha<sup>-1</sup> compared to control), beef: 11.80 c ha<sup>-1</sup> (+3.03 c ha<sup>-1</sup> compared to control), milk: 105.09 c ha<sup>-1</sup> (+26.94 c ha<sup>-1</sup> compared to control). Economic indicators also have positive dynamics: profitability from the use of flat grain in the proportion of 8:92% increases 1.8 times as compared to control, net income elevates by 17195 rubles ha<sup>-1</sup>, while the cost of 1 kg of digestible protein obtaining is reduced by 18%.

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