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Issues of forage quality under industrial milk production in the south of Ukraine

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The purpose of the article is to determine the average quality of traditional forage (maize silage and alfalfa haylage) and innovative dietary components – rye silage on the example of average milk production farms in Odesa Oblast with moderate and intensive levels of technological process and to determine the impact of the risky land use zone in the South of Ukraine against the background of global warming on the quality of these dietary ingredients in order to determine further directions of forage production in the southern region of Ukraine. Scientific and economic experiments were conducted in Odesa Oblast according to the methods generally accepted in dairy farming, and laboratory studies of corn silage, alfalfa haylage, rye silage samples in a specialized laboratory for forage research using the NIRS technique were used to assess the quality of forages. NIRS has been successfully used in the prediction of nutritional value through direct scanning of forage samples. The analysis of corn silage shows that the basic indicators of its quality, such as dry matter content, metabolizable energy concentration, pH, level of digestibility of organic matter as a percentage of total dry matter, and starch content are below the existing standards, because due to hot weather conditions, silage is often forced to be harvested during the suboptimal phase of its maturity. An assessment of the mineral composition of corn, rye and alfalfa silage shows that the indicators are typical, taking into account the specifics of each crop in the southern region of Ukraine, so the existing deficit of manganese, cobalt, zinc and copper can be covered with the use of specialized premixes. Due to the difficulties of agrotechnical cultivation of corn silage and alfalfa haylage, which has recently developed in the risky land use zone of southern Ukraine and against the background of global warming, fodder crops have to be grown in more favorable (wet) seasons of the year, such as winter rye or triticale, etc. or their combination with corn silage and alfalfa haylage.

Key words: dairy cows, corn silage, rye silage, alfalfa haylage, analysis, forage production process.

Питання якості фуражних кормів за промислового виробництва молока в умовах півдня України

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Мета роботи – визначення середньостатистичної якості традиційних фуражних кормів (кукурудзяного силосу і люцернового сінажу) та інноваційних складових раціону – житнього силосу на прикладі пересічних господарств з виробництва молока Одеської області з помірним та інтенсивним рівнями технологічного процесу та визначення впливу зони ризикованого землекористування півдня України на фоні глобального потепління на якість цих інгредієнтів раціону з метою подальшого визначення напрямів кормовиробництва у південному регіоні України. Науково-господарські дослідження проведено в умовах Одеської області за загальноприйнятими у молочному тваринництві методиками, а лабораторні дослідження зразків кукурудзяного силосу, люцернового сінажу, житнього силосу в умовах спеціалізованої лабораторії з дослідження кормів з використанням методики інфрачервоної спектроскопії (NIRS) була використана для оцінки якості кормів, оскільки NIRS успішно використовується для прогнозування поживної цінності шляхом прямого сканування зразків кормів. Проведений аналіз кукурудзяного силосу засвідчує, що базові показники його якості на вміст сухої речовини, концентрація обмінної енергії, рівень pH, рівень перетравності органічної речовини від загального

складу сухої речовини, вміст крохмалю знаходяться нижче існуючих нормативних показників, тому що через спекотні погодні умови силос часто вимушено починають збирати під час неоптимальної фази його зрілості. Оцінка мінерального складу кукурудзяного, житнього силосів і люцернового сінажу засвідчує типовість показників з урахуванням специфічності кожної культури для південного регіону України, тому існуючий дефіцит марганцю, кобальту, цинку і міді цілком можна покрити за рахунок використання спеціалізованих преміксів. У зв'язку зі складнощами агротехнічного вирощування кукурудзи на силос та люцернового сінажу, що складається останнім часом в зоні ризикованого землекористування півдня України та на фоні глобального потепління, виникає необхідність переходу до кормових культур, що вирощуються у більш сприятливі (зволожені) сезони року на кшталт озимого жита або тритикале, тощо або їх комбінації з кукурудзяним силосом та люцерновим сінажем.

Ключові слова: дійні корови, кукурудзяний силос, життній силос, люцерновий сінаж, аналіз, процес кормовиробництва.

Introduction

The livestock breeding industry is a rather dynamic sector of agricultural production. It provides people with animal protein. Like any industry, it faces various challenges for its development. One of the most recent barriers is the information about global warming, which is associated with cattle breeding. At the same time, Professor Dr Wilhelm Windisch notes that challenging the myth livestock was considered by many to “pollute the environment” and “compete with humans for food”. Livestock delivers high quality food protein and kilocalories from a given agricultural area equivalent to 50–100 % of primary vegan food without food competition, solely from the circulation of inevitably occurring, non-edible biomass, while delivering fertilizers and promoting vegan production. Concluding he said, the impact of livestock feeding on the environment and climate had 2 steps: 1) Feeding within circularity: fully sustainable, but limited and low-input production capacity 2) Feeding through food competition: a burden to the environment and climate but highly productive ([website: All about Feed, 2023](#)).

There are other problems in dairy farming, such as the fact that milk production is carried out with low levels of technology, mainly on small farms, which leads to low levels of productivity, reproductive capacity, hygiene and inefficient management, which is more typical for developing countries ([Astaiza Martinez et al., 2017](#)).

High feed costs have cut deeper into dairy farmers pockets, especially as milk prices continue to sink lower and lower. According to the University of Minnesota, over the last decade, total feed costs of a dairy herd have become a better predictor of profitability than milk production. With no end to the higher feed cost trend in sight, farmers are looking at ways to get the most out of their rations while minimizing wasted feed ([website: Dairy herd Management, 2023](#)).

Another relevant problem is the quantity and quality of fodder. The lack or inadequate quality of feed often leads to metabolic problems: subclinical acidosis, ketosis, etc. ([Garzon & Espinosa, 2018](#); [Vallejo-Timaran et al., 2020](#)).

Nutrition management needs to be improved ([Eadie, 2019](#)).

Optimization of the technology for rearing replacement cattle, taking into account the specific needs of a particular dairy breed and their growth patterns, is always a topical issue in dairy farming today. The growth of young cattle directly depends on the genotype and strength of the feed base, the key place in the formation of which is occupied by forage ([Pidpala et al., 2019](#); [Kramarenko et al., 2022](#)).

At the same time, the production of quality milk remains an important challenge. The term “milk of optimal quality” means milk containing at least 3.0 % protein and more (milk suitable for cheese production) and, accordingly, 3.6 % fat and more, but with the obligatory compliance with the fat: protein ratio of 1.2 : 1, which primarily indicates the absence of metabolic disorders in the cow's body, such as acidosis, ketosis, etc. It is quite difficult to achieve the required balance between protein and fat in cow's milk without the rational use of fodder in practical production conditions, especially without the use of special additives such as rumen buffers, etc.

The question often arises as to which forage is better: hay, haylage, silage? High-quality hay has a positive effect on the formation of rumen microflora and high productivity of dairy herds, but hay has few prospects for its use on a modern industrial-scale dairy farm ([Susol, 2018](#)).

The nutritional characteristics of triticale harvested at the tube stage are more desirable for lactating cows than triticale harvested at later stages of maturity, when fibre content increases and crude protein content decreases, but approximately 70.0 % of the yield loss can also be attributed to this management choice. Despite these differences, an informed management decision for lactating cows may still favour harvesting early due to better nutritional characteristics, the need to quickly plant a double crop of maize, or both. The timing of triticale harvesting for other livestock classes may be more flexible, but prioritising a double crop of maize, soybean or sorghum may reduce the negative impact on dry matter yield of a secondary factor ([Coblentz et al., 2018](#)).

Grass silage-based diets often result in poor nitrogen utilization when fed to dairy cows. Perennial ryegrass cultivars with high concentrations of water-soluble carbohydrates (WSC) have proven potential for correcting this imbalance when fed fresh, and have also been shown to increase feed intake, milk production, and N utilization ([Bertilsson et al., 2017](#)).

The aim of our work

The aim of our work is to determine the average quality of traditional fodder (corn silage and alfalfa haylage) and innovative dietary components – rye silage on the example of average milk production farms in Odesa Oblast with moderate and intensive levels of technological process and to determine the impact of the risky land use zone of southern Ukraine against the background of global warming on the quality of these dietary ingredients in order to further determine the directions of fodder production in the southern region of Ukraine.

Material and methods

The scientific and economic experiments were conducted in the conditions of the State Enterprise “Andriivske” (moderate level of production technology) and LLC “Shabo Farm” (intensive level of production technology) of Bilhorod-Dnistrovskiyi district of Odesa Oblast according to the methods generally accepted in dairy farming (Ibatulina & Zhukorskoho, 2017), and laboratory studies of samples of corn silage, alfalfa haylage, rye silage in a specialised forage research laboratory Frank Wright LTD (Ashbourne, United Kingdom) using the NIRS technique has been used to assess the quality of forages (Carvalho da Paz et al., 2019). NIRS has been successfully used in the prediction of nutritional value through direct scanning of forage samples (Stuth et al., 2003; Boschma et al., 2017). In the laboratory, each of the indicators was determined in at least 10 replicates, so the result presented here is the arithmetic average.

Samples of fodder were taken using a Nasco sampler from different parts and at different heights of the silage or haylage storage facilities in 2.0 kg each. Then the sample was thoroughly mixed and 0.5 kg was taken using the square method for further vacuuming and air delivery to the laboratory. The research was conducted in November 2021.

Results

Due to climate change over the past 10–15 years, it has become increasingly difficult to grow corn for silage and alfalfa for hay in southern Ukraine, so we need to think about promising, drought-resistant and at the same time efficient crops that can be an alternative to corn and alfalfa. One of the most promising crops for forage production in southern Ukraine could be winter rye or any other winter crop that can be silage.

The analysis of the actual results of corn silage yields (Fig. 1) indicates the presence of relatively productive years (2010, 2017, 2018, 2021, where the yield was from 165 to 234 c/ha) and problematic years (2000, 2015, 2016, 2019, 2020, 2022, where the yield was from 52 to 123 c/ha). Thus, out of the last eight years of the period 2015–2022, four years, equivalent to 50.0 %, were problematic in terms of silage yield, and this is without taking into account the quality issue, as due to droughts, harvesting begins before the grain reaches milky-wax ripeness, which means a deficit of starch and metabolic energy.

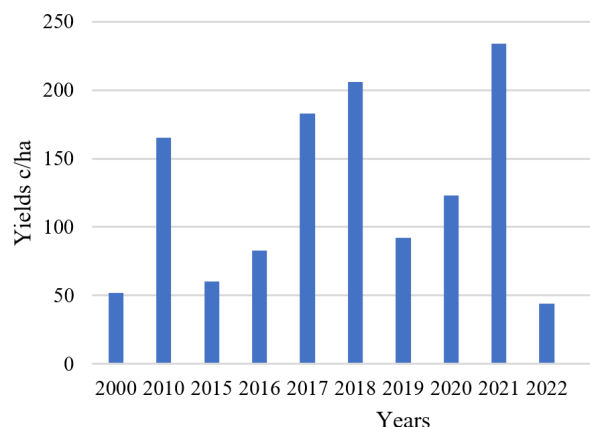


Fig. 1. Dynamics of corn silage yield in Odesa Oblast

Thus, in the conditions of local farms, corn silage remains the main available juicy forage for the dairy herd. The actual general analysis of corn silage in the conditions of a farm with a moderate level of technology (without the use of preservatives, laying time of 4–5 days) proves (Table 1) that the content of dry matter and crude protein in the silage is within the normal range (32.0–38.0 %) – 32.9 % and (7.0–9.0%) – 7.6 %, respectively. The energy concentration in this sample was 10.4 MJ/kg dry matter, which is below the norm of 11.6–12.4 MJ/kg dry matter, which is primarily due to the starch content, the actual content of which is too low at 23.5 % (the normative indicator is 35.0–45.0 %). The proper pH level was found to be 4.0 (normal pH is 3.9–4.2) against the background of an overestimated lactic acid content (70.1 g/kg in fact, while the norm is 25.0–50.0 g/kg). The content of ammonia nitrogen in total nitrogen is actually 5.5 %, while the permissible norm is 4.0 % or less, which indicates an increased likelihood of decay. The actual crude ash content reached 4.5 %, which is in line with the current standard of 4.0–5.0 % and indicates that the silo is not contaminated by soil. The actual content of neutral-detergent fibre in the silage was 53.1 %, which is higher than the existing standard (35–45 %). The situation is similar with acid-detergent fibre (52.26), which is significantly higher than the standard (27.8 and 28.0–36.0 %), which to some extent affects the calculated (projected) consumption rate, which is also below the existing standard (110–130) – 101.2 g/kg, respectively.

Table 1

Forage analysing (Dry Matter) maize and rye silage and lucerne haylage

Indicator	maize silage *	maize silage**	lucerne haylage **	rye silage*
Dry matter, %.	32.9	27.5	35.1	23.3
ME, MJ/kg	10.4	11.1	9.5	11.0
Crude protein, % DM	7.6	9.6	23.4	12.7
D Value, %.	66.2	69.9	73.1	69.0
pH	4.0	3.7	4.9	4.8
NH3-N in total N, %.	5.5	2.9	14.0	7.1
Ash, %.	4.5	4.6	12.6	8.2
Starch, %.	23.6	15.3	-	-
NDF, %.	38.2	55.1	33.9	51.9
Lactic acid, g/kg	70.1	96.5	59.0	43.1
Intake, g/kg of ML	101.2	98.4	89.9	96.4

Notes (hereinafter): * - in farm conditions with a moderate level of technology (without the use of preservatives); ** - in the conditions of a farm with an intensive level of technology (with the use of preservatives).

Evaluation of the results of average samples of corn silage in 2021, which were laid in the conditions of a farm with an intensive level of technology in dairy farming: the use of hybrid corn varieties, the use of special preservatives, the timing of laying one pit in 2–3 days proves that the dry matter content in corn silage is slightly lower than the existing norm (32.0–38.0 %) – 27.5 % against the background of an increased crude protein content of 9.6 % at a norm of 7.0–9.0 %.

The energy concentration in this sample was 11.1 MJ/kg dry matter, while the norm is 11.6–12.4 MJ/kg dry matter, which is primarily due to the starch content, the actual content of which was only 15.3 % (the normative value is 35.0–45.0 %). A low pH of 3.7 was found (normal pH is 3.9–4.2), which will contribute to acidosis and is caused by an overestimated lactic acid content (96.5 g/kg in fact, while the norm is 25.0–50.0 g/kg). The content of ammonia nitrogen in total nitrogen is actually 2.9 %, while the permissible rate is 4.0 % or less, indicating the absence of decay processes. The actual content of crude ash reached 4.6 %, which corresponds to the existing norm of 4.0–5.0 % and indicates that the silage is not contaminated with soil.

Table 2
The mineral analysis of maize and rye silage, lucerne haylage

Indicator	maize silage *	maize silage**	lucerne haylage **	rye silage *
Calcium, %.	0.29	0.58	3.05	0,45
Phosphorus, %.	0.20	0.18	0.85	0.42
Magnesium, %.	0.22	0.25	0.47	0.16
Sodium, %	0.01	0.23	0.15	0.05
Potassium, %	0.64	1.79	1.13	1.34
Chlorine, %	0.17	0.70	0.31	0.90
Sulphur, %.	0.09	0.14	0.35	0.20
Iron, mg/kg	357.3	456.1	921.2	373.5
Copper, mg/kg	4.2	5.3	10.3	8.85
Manganese, mg/kg	32.4	64.6	117.3	74.5
Cobalt, mg/kg	0.05	0.14	0.32	0.08
Zinc, mg/kg	15.8	26.3	32.2	29.9
Selenium, mg/kg	0.059	0.107	0.16	0.12
Aluminium, mg/kg	45.5	393.2	1158.0	48.8
Lead, mg/kg	0.16	0.39	0.56	0.22
Molybdenum, mg/kg	0.82	0.43	0.51	0.79

For example, the content of macronutrients such as calcium, magnesium, sodium, potassium, chlorine, sulphur, and the content of macronutrient selenium meets the existing standards; iron and aluminium exceed the optimal level, while manganese, cobalt, zinc and copper are in deficit.

Modern dairy cattle rations for industrial production involve the use of alfalfa haylage, which, according to many scientists and practitioners, is an excellent supplement to corn silage-based rations and saves on expensive protein ingredients in feed. The actual overall analysis of alfalfa haylage showed that the dry matter content of 35.1 % is well within the average samples tested by the laboratory in 2021 (35.2 %), but the crude protein content of 23.4 % is significantly higher than the average laboratory samples (19.4 %), which further emphasizes the value of this ingredient. Typical for alfalfa haylage is the low sugar content (12.0 %) and the absence of starch. The

The actual content of neutral-detergent fibre in the silage was 55.1 %, which is higher than the existing standard (35–45 %). At the same time, the content of acid-detergent fibre is within the upper limit of the standard (27.8 and 28.0–36.0 %, respectively). The estimated (forecasted) consumption rate is below the existing standard (110–130) – 98.7 g/kg. The indicator of feed conversion into milk has an actual content of 305.0 units in this silage, which is below the norm (320–380 units), which in turn can lead to a decrease in rumen pH and cause acidosis.

Regarding the assessment of the mineral composition of silage in a farm with a moderate level of technology (Table 2), it is worth noting that it is, on the one hand, typical for the southern region of Ukraine – the content of macronutrients such as phosphorus, magnesium, sulphur and the content of trace elements such as selenium meets the existing standards; iron, aluminium exceed the optimal levels, while sodium, potassium, sulphur, manganese, cobalt, zinc and copper are at a deficient level. The low calcium content is atypical in this case, as it is usually sufficient in the silage due to the high level in the soil.

slightly lower content of neutral detergent fibre (33.9 %), acid detergent fibre (25.3 %) and acid detergent lignin (49.0 %) compared to the average laboratory samples (42.2 %, 32.5 % and 61.0 %, respectively) results in a higher crude protein content.

Our actual mineral analysis of alfalfa haylage showed that this ingredient is rich in macronutrients: calcium, phosphorus, sulphur, and trace elements: iron, cobalt, selenium, aluminium, and copper. It has been established that alfalfa haylage has a moderate content of sodium, manganese, molybdenum, and copper. Alfalfa haylage is low in potassium, chlorine, zinc and, of course, lead. Again, we can see that there is an increased iron content, but it is levelled out by the above-mentioned antagonist, aluminium.

In general, it should be noted that if we optimize the timing of alfalfa for haylage, we get fodder with an optimal level of dry matter and an increased level of crude

protein. As for the mineral composition of alfalfa haylage, it can be considered typical for the south of Ukraine.

In our opinion, rye silage is most promising for forage production in the South of Ukraine, as its growing season is more humid (autumn, winter, spring). Thus, in terms of dry matter content, rye haylage is significantly inferior to corn silage by 9.6 %, but rye silage is 5.1 % higher in terms of crude protein and 2.8 % higher in terms of organic matter digestibility. In terms of metabolizable energy, rye silage also has an advantage of 0.6 MJ/kg dry matter under moderate feed production technology and has a more alkaline environment by 0.8 units, an increased level of ammonia nitrogen from total nitrogen by 1.6 %, and an increased level of ash by 3.7 % compared to corn silage.

Of course, corn silage is rich in starch, with a content of 23.6 %, which is not present in rye haylage. However, on the other hand, high starch levels can cause metabolic disorders such as acidosis with subsequent problems with reproduction and reduced productive longevity of the herd, etc. On the contrary, rye haylage is a more natural feed for cattle and contributes to the level of herd safety.

In terms of such a critically important indicator as neutral-detergent fibre for ruminants, rye silage has a significant advantage of 13.7 % under moderate feed production technology. The content of lactic acid is 27.0 % higher in corn silage, which is quite natural due to the presence of starch.

These feed ingredients differ from each other and from the predicted consumption by 4.8 g/kg in favors of corn silage under moderate feed production technology, but this is only a laboratory calculation, and the effectiveness of each of these ingredients can be assessed only through actual use in feeding dairy cows.

Discussion

We understand that cattle are ruminants, therefore, for the effective functioning of these individuals and the production of the desired amount of milk with optimal quality, ruminants need a certain amount of fodder (approximately at least 60.0 % of the dry matter of the diet is the proportion of fodder in the structure of a “healthy” diet). In the current realities of “domestic technologies” of feeding, the available fodder is corn silage, haylage and hay of cereals or legumes, straw, etc. (Provatorov et al., 2007; Ruban & Vasylevskyi, 2015; Riznychuk, 2016; Riznychuk et al., 2023).

Forages are the basis for the formation of a healthy cow's diet (Nasr et al., 2017), as inadequate nutritional management of the studied herds in the pre- and postpartum period increased the incidence of subacute ruminal acidosis during the first 60 days after calving and increased the risk of anestrus at 60 days after calving, as well as other adverse effects on reproductive performance. Feeding a transitional ration is an important tool for the adaptation of rumen microflora to feed additives and improving reproductive performance (Stefanska et al., 2017).

Increasing the ratio of NDF to starch in the diet promotes the development of rumen papillae and alters the expression of genes associated with rumen papillae uptake, metabolism and cell growth (Ma et al., 2017). In this

case, the use of rye silage in the diets increases the ratio of NDC to starch in the diets.

There is a lot of information on the benefits of maize silage as an easily digestible ingredient that provides high energy intake when used in dairy cow diets (website: Dairy Global), but currently, globally, maize is the third most important crop in terms of harvested area. Due to its importance, assessing variations in regional climatic suitability under climate change is critical.

The potential current and future climatic distribution of maize on a global level was modelled using the CLIMEX distribution model with climate data from 2050 to 2100. The change in area under future climate was analyzed at the continental level and for the major maize-producing countries in the world. The tropical regions, South America, Africa and Oceania show the greatest loss of climatic suitability for maize cultivation. At the same time, Asia, Europe and North America are showing an increase in climatic suitability.

This study indicates that, globally, large areas currently suitable for maize cultivation will suffer from heat and drought, which may limit maize production (Ramirez-Cabral et al., 2017). In such circumstances, the transition to silage harvesting from winter cereals is a promising way out of this situation, which has recently developed in the risky land use zone of southern Ukraine and against the background of global warming.

Conclusions

The analysis of corn silage shows that the basic indicators of its quality, such as dry matter content, concentration of metabolizable energy, pH, level of digestibility of organic matter as a percentage of total dry matter, and starch content are below the existing standards, because due to hot weather conditions, silage is often forced to be harvested during the suboptimal phase of its maturity. It is worth noting that this situation is not uncommon in the southern region in the context of ongoing global warming.

Comparing the mineral composition of different levels of technology, a common pattern of typical deficiencies in phosphorus, sulphur, manganese, cobalt, and zinc can be observed. The situation with calcium content is ambiguous. In addition, it is worth noting that elevated iron levels are not a problem because aluminium, which is its antagonist, is also in excess.

The content of heavy metals lead and molybdenum is at a low level, as required by environmental safety.

An assessment of the mineral composition of corn, rye silage and alfalfa haylage shows that the indicators are typical, taking into account the specifics of each crop in the southern region of Ukraine, so the existing deficit of manganese, cobalt, zinc and copper can be covered by the use of specialized premixes.

Due to the difficulties of growing corn silage and alfalfa haylage in the recent risky land use zone of southern Ukraine and against the background of global warming, it is necessary to move to fodder crops grown in more favourable (wet) seasons, such as winter rye or triticale, or a combination of these with corn silage and alfalfa haylage.

Conflict of interest

The authors declare that there is no conflict of interest.

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