Barbara WRÓBEL[1], Krystyna ZIELIŃSKA[2], Agata FABISZEWSKA[3]
[1] Institute of Technology and Life Sciences, Department of Grassland Farming, Falenty, Poland
[2] Prof. Wacław Dąbrowski Institute of Agricultural and Food Biotechnology, Department of Fermentation Technology, Warsaw, Poland
[3] Warsaw University of Life Sciences, Poland
e-mail: b.wrobel@itep.edu.pl

THE IMPACT OF FERTILIZATION USING NATURAL FERTILIZERS ON THE QUALITY OF GRASS SILAGE

Summary

The study was conducted between 2008 and 2010 at the Experimental Farm of the Institute of Land Reclamation and Grassland Farming (currently the Institute of Technology and Life Sciences) in Falenty, Mazovian voivodeship, in the form of a field experiment on an area of permanent grassland. The study aimed to assess the influence of different forms and quantities of fertilizer on the quality, nutritional value and presence of pathogenic microorganisms in silage made of meadow sward. The experiment involved a field divided into six zones, each with an area of ~0.3 ha, which were fertilized using inorganic NPK fertilizers, liquid manure (fermented cattle urine) or solid manure applied in two quantities, giving two levels of nitrogen fertilization: 60 and 90 kg·ha^{-1}. Meadow sward from the first cut was partly dried (40% dry weight), harvested with a round baler and ensilaged in large cylindrical bales. Tests on samples of the sward and silage were carried out to examine levels of yeasts, moulds, potentially pathogenic bacteria and nutrients. The silage samples were tested in respect of dry matter, pH level, and levels of lactic acid, volatile fatty acids and ammonia. Fertilization with manure helped to produce green fodder and silage of a higher nutritional value but sward from meadows fertilized with manure constituted a poorer feedstock for silage (poor sugar / protein ratio) than sward fertilized with liquid manure. Fertilization with liquid manure yielded fodder with a nutritional value close to fodder from meadows fertilized with inorganic fertilizer. Fertilization of sward with liquid manure did not hinder the process of fermentation. At the same time our research indicates that the process of lactic fermentation can be effective in limiting the abundance of pathogenic bacteria in silage.
***Key words**: pathogenic microbes, liquid manure, silage, fertilization, solid manure, meadow sward*

WPŁYW NAWOŻENIA ŁĄKI TRWAŁEJ NAWOZAMI NATURALNYMI NA JAKOŚĆ SIANOKISZONKI

Streszczenie

Badania prowadzono w latach 2008–2010 w Zakładzie Doświadczalnym IMUZ (obecnie ITP) w Falentach, na doświadczeniu łanowym na łące trwałej. Celem badań była ocena wpływu stosowania różnych form i dawek nawozów na jakość, wartość pokarmową i obecność szkodliwych mikroorganizmów w kiszonce z runi łąkowej. W ramach badań na łące wydzielono 6 łanów (obiekty doświadczalne), każdy o powierzchni ok. 0,3 ha, które nawożono nawozami mineralnymi NPK oraz gnojówką bydlęcą i obornikiem stosowanymi w dwóch dawkach, odpowiadających dwóm poziomom nawożenia azotem: 60 i 90 kg·ha^{-1}. Ruń łąkową z pierwszego pokosu, po wstępnym podsuszeniu (40% s.m.) zbierano prasą rolującą i zakiszano w dużych belach cylindrycznych. W próbach zielonki i kiszonki oceniano liczebność drożdży, grzybów pleśniowych oraz bakterii potencjalnie chorobotwórczych a także zawartości składników pokarmowych. W próbach kiszonek ponadto oceniano poziom suchej masy, wartość pH świeżej masy kiszonki, zawartość kwasu mlekowego, lotnych kwasów tłuszczowych i udział amoniaku. Nawożenie obornikiem sprzyjało uzyskaniu wyższej wartości pokarmowej zarówno zielonki jak i uzyskanej z niej kiszonki. Mimo to ruń łąkowa z łąki nawożonej obornikiem stanowiła gorszy materiał na kiszonki (niekorzystny stosunek cukry/białko) niż ruń nawożona gnojówką. Po nawożeniu gnojówką uzyskano paszę o wartości pokarmowej zbliżonej do paszy z łąki nawożonej nawozami mineralnymi. Nawożenie runi łąkowej gnojówką nie utrudniło procesu fermentacji. Jednocześnie wykazano, że proces fermentacji mlekowej może być efektywnym narzędziem ograniczającym liczebności chorobotwórczych bakterii w kiszonce.
***Słowa kluczowe**: drobnoustroje patogenne, gnojówka bydlęca, kiszonka, nawożenie, obornik, ruń łąkowa*

1. Introduction

In recent years there has been an increase in interest in natural fertilizers in Poland mainly due to the increasing prices of inorganic fertilizers. The number of organic farms, which only use natural fertilizer on their grasslands, has also increased. The natural fertilizers most frequently used on permanent grassland include: solid manure, liquid manure (fermented urine) and slurry [1-3].

Manure, especially cow manure, is the best form of natural fertilizer for permanent grassland, ideally in a fermented or composted form [3-5]. It contains all the nutritional elements needed for the feeding of plants but also organic matter and complex microflora. Manure is a congealed mixture of bedding straw and solid and liquid waste from farm animals. The fermented urine of farm animals is a fast-acting liquid nitrogen-potassium fertilizer. Unfortunately it contains low levels of phosphorus and other minerals such as calcium and magnesium, which requires supplementary fertilization using inorganic phosphorus [1-2].

The fertilizing qualities of manure and fermented urine depend upon its animal species of origin, how much bedding straw is added, how has been stored and for how long. These fertilizers can be used annually between 1 March and 30 November, but only if their total dose of Nitrogen does not exceed 170 kg ha^{-1} [6]. For environmental reasons the best time to apply solid manure on permanent grassland is in early spring but it can also be used in late autumn [1-2]. Fermented urine can only be applied on permanent grassland during the vegetative period after and only once it has been stored for five to six months in airtight tanks and allowed to ferment [1-2].

Natural fertilizers, despite their many benefits, present a habitat for various pathogens, parasites and microbes that can be detrimental to the silage fermentation process, such as *Clostridium* and *Bacillus* bacteria which, when ingested by dairy cattle, also have a negative impact on the quality of milk and its usefulness for processing into dairy products. The presence in fodder of pathogenic microbes carries the risk that they will spread, through animals, to foodstuffs and raw materials of animal origin, which can be harmful to human health [7-9].

At the same time ensiling is becoming an increasingly widespread method of preserving meadow sward. On average more than 25% of harvested permanent grassland, typically from the first cut, is processed into silage [10]. This trend goes hand in hand with changes in to systems for feeding dairy cattle which include a growing role for silages. There is therefore a clear need to examine the influence of fertilization with natural fertilizer on the suitability of sward for ensilage and the quality of the resulting silage [11-13].

Recognising the benefits of organic fertilizer as a fertilizer, we set out to evaluate the influence of different types and quantities of fertilizer (organic and inorganic fertilizer) on the quality, nutritional value and presence of harmful microorganisms in silage made from meadow sward.

2. Materials and methods

The research was conducted between 2008 and 2010 at the Institute of Land Reclamation and Grassland Farming (currently the Institute of Technology and Life Sciences) in Falenty, Mazovian voivodeship, in the form of a field experiment on an area of permanent grassland in proper dry meadow conditions on degraded black soil with a granulometric composition consistent with loamy soil. The meadow was divided into six zones, each with an area of ~0.3 ha, which were used to compare the effect of fertilization using inorganic NPK fertilizers, liquid manure (fermented cattle urine) and solid caw manure, each applied in two different quantities, giving two levels of nitrogen fertilization. The first level of fertilization was obtained by adding 60 kg N, 30 kg P and 60 kg K·ha^{-1} while 90 kg N, 45 kg P and 90 kg K·ha^{-1} were added for the second level. The inorganic fertilizers were ammonium nitrate, ground phosphate rock and potassium sulphate. One third of the annual dose of inorganic nitrogen and potassium fertilizer was applied for each harvest while the phosphorus was applied once year in spring.

Manure (20% DM) was applied once a year in autumn (in 2008 and 2009) or spring (in 2010) with a manure spreader after storage for a period of six months on a manure pad. The liquid manure (fermented caw urine), fermented for at least five to six months in a tank, was applied to soil using a rotary hoe in two equal doses – in spring and after the first harvest. Depending on the nitrogen level in the manure and liquid manure at the first fertilization level (N-60) in the following years between 24.0 and 30.0 t ha^{-1} of manure, and between 24.0 and 28.0 m^3 ha^{-1} of liquid manure were added. At the higher level of fertilization (N-90) the doses of fertilizer were increased by 50%. Shortfalls in phosphorus in zones fertilized with liquid manure were supplemented with ground phosphate rock.

The six experimental zones were mowed using a rotary mower three times a year. The first harvest was carried out between 19 and 28 May, the second between 13 and 22 July and the third between 21 and 29 September. During the harvest samples of sward were collected for chemical and microbiological analysis. The mowed sward from the first harvest was dried to around 40% DM, harvested using a rotary baler and fermented in large cylindrical bales weighing approximately 400 kg each. Three large bales were made from each zone. Once formed, the bales were transported to a storage area where they were wrapped in four layers of foil. In November, using a special probe, two average samples of fodder were collected from each bale of silage for chemical analysis.

The sward samples were dried, ground and their nutritional value was analysed (using the NIRS method with a NIRFlex N-500 using hay presets created by INGOT®). The samples of fresh silage were assessed for dry matter (oven method at a temperature of 105ºC), fresh weight pH of silage (using the potentiometric titration method), lactic acid content, volatile fatty acid content, ammonia content and levels of basic nutritional components (using the NIRS method with the NIRFlex N-500 spectrometer using silage presets created by INGOT®).

In addition, the fresh samples of sward and silage were used to measure the overall level of aerobic bacteria, bacteria of the *Enterobacteriaceae* family including bacteria of the *coli* group, and to enumerate yeast and moulds cells using the culture method on 3M Petrifilm^{TM} count plates. In 2010 the sward and silage were tested for the presence of *Salmonella spp.* cells and *Bacillus cereus* bacteria.

The collected data were subjected to statistical analysis using one-way analysis of variance. The calculations were made using the Anova module of the Statistica package. Comparison of means and division into homogenous groups was carried out using the Tukey test (HSD) with an α level of p≤0,05 being deemed as significant.

3. Results

3.1. The chemical components of sward

The basic nutrient content of meadow sward fertilized with liquid manure, irrespective of the quantity of fertilizer applied, was found to be similar to the content of sward from a zone fertilized with inorganic fertilizer. This was particularly the case for total protein, crude fibre and its fractions. Sward fertilized with manure, irrespective of quantity, was characterised by a significantly higher quantity of total protein and crude ash than sward from other zones. There were also differences in fibre fractions. Sward from zones fertilized with manure was found to contain greater amounts of ADL and ADF fractions and less NDF, which indicates the lower digestibility of this material (Table 1).

Water soluble carbohydrates are an important part of the chemical makeup of green fodder. They provide a source of energy for the bacteria responsible for lactic fermentation, an essential part of the ensilage process. The study found that the applied fertilizer also had a significant influence on levels of this component. In sward fertilized with manure the sugar content was on average 51.9 g·kg^{-1} lower than in sward fertilized with inorganic fertilizer and 62.6 g·kg^{-1} lower than in sward fertilized with liquid manure. The highest, and therefore the most beneficial sugar to protein ratio for ensilage, was found in sward from zones fertilized with liquid manure while the lowest ratio was found in sward from zones fertilized with manure, which indicates that this form of fertilizer is less suitable for growing sward for ensilage.

3.2. The microbiological quality of sward

Neither of the applied organic fertilizers, manure or liquid manure, had a negative impact on the microbiological assessment of silage sward. The average of the total number of aerobic microbes, bacteria of the *Enterobacteriaceae* group, bacteria of the *Bacillus cereus* group, and yeasts and moulds found on plants fertilized with organic fertilizers was of a similar level to green fodder from zone fertilized with NPK fertilizers. The number of *E. coli* bacteria was significantly higher only in green fodder made from sward grown on a zone fertilized with liquid manure compared to other zones, i.e. zones fertilized with manure and NPK fertilizers. All green fodder samples were free from *Salmonella* spp. bacteria (Table 2).

3.3. Nutritional value and quality of silage

All of the three forms of fertilizer studied had a significant impact on the ensilage process and on the majority of indicators used to assess silage quality. The dry matter of the silage samples examined totalled on average 300 g·kg^{-1}, which indicates ideal conditions for fermentation. The pH of fresh weight silage was at its lowest level (4.12 and 4.19 accordingly) in silage made from sward from both zones fertilized with liquid manure and zones fertilized with inorganic fertilizer. The pH reached its highest levels in silage from both zones fertilized with manure. Ammonia content followed a similar trend to pH value. The lowest ammonia levels were found in silage from zones fertilized with liquid manure while the highest were found in silage from sward fertilized with manure (Table 3).

A strong correlation was also found between fertilization and the levels of organic acids in silage. The highest level of lactic acid, totalling nearly 55 g kg^{-1} DM of silage, was observed in silage made from sward fertilized with liquid manure. Significantly lower levels of lactic acid were found in silage from the zones fertilized with manure.

Table 1. Chemical composition of I cut meadow sward fertilized with manure, liquid manure and mineral fertilizers, mean from years 2008-2010

Tab. 1. Skład chemiczny runi łąkowej z I pokosu nawożonej obornikiem, gnojówką i nawozami mineralnymi, średnie z lat 2008-2010

Examined parameter	Fertilization level	Value of parameter in sward from objects		
		fertilized with inorganic fertilizers	fertilized with manure	fertilized with liquide manure
Total protein content, g·kg^{-1} DM	N-60	105.8a	123.4b	98.6a
	N-90	97.5a	113.7b	101.5a
	mean	**101.6a**	**118.6b**	**100.0a**
Crude fibre content, g·kg^{-1} DM	N-60	284.8	290.0	282.6
	N-90	276.9b	300.2c	264.0a
	mean	**280.8a**	**295.1b**	**273.3a**
Crude ash content, g·kg^{-1} DM	N-60	76.8a	88.8b	74.7a
	N-90	76.6a	88.3b	84.4b
	mean	**76.7a**	**88.5b**	**79.5a**
NDF content, g·kg^{-1} DM	N-60	500.7	497.8	496.5
	N-90	493.7a	524.3b	478.2a
	mean	**497.2ab**	**511.1b**	**487.3a**
ADF content, g·kg^{-1} DM	N-60	326.7	339.9	326.4
	N-90	321.9a	351.3b	318.0a
	mean	**324.3a**	**345.6b**	**322.2a**
ADL content, g·kg^{-1} DM	N-60	40.5	44.9	39.8
	N-90	37.6a	45.4b	37.6a
	mean	**39.1a**	**45.1b**	**38.7a**
Water soluble sugars content, g·kg^{-1} DM.	N-60	156.8b	115.8a	169.4b
	N-90	176.8b	114.1a	185.6b
	mean	**166.8b**	**114.9a**	**177.5b**
Dry matter digestibility, %	N-60	54.78	53.84	55.18
	N-90	56.35b	51.40a	58.86c
	mean	**55.56b**	**52.63a**	**57.02b**
Sugars/protein ratio	N-60	1.50b	0.95a	1.77c
	N-90	1.83b	1.01a	1.85b
	mean	**1.67b**	**0.98a**	**1.81b**

Explanations: N-60 – fertilization in amount (in kg·ha^{-1}): N-60, P-30, K-60;
N-90 - fertilization in amount (in kg·ha^{-1}): N-90, P-45, K-90;
a, b, c – significance of differences at $p \leq 0.05$;
NDF – neutral detergent fibre (hemicellulose + cellulose + lignin); ADF – acid detergent fibre (cellulose and lignin); ADL – lignin

Source: Own work / Źródło: opracowanie własne

Table 2. Count of individual groups of microorganisms (log $cfu \cdot g^{-1}$ FM) in meadow sward fertilized with manure, liquid manure and mineral fertilizers, mean from years 2009-2010

Tab. 2. Liczebność poszczególnych grup mikroorganizmów (log $jtk \cdot g^{-1}$ św. m.) w runi łąkowej nawożonej obornikiem, gnojówką i nawozami mineralnymi, średnie z lat 2009-2010

Examined parameter	Fertilization level	Value of parameter in sward from objects		
		Fertilized with inorganic fertilizers	Fertilized with manure	Fertilized with liquide manure
Yeasts	N-60	1.06	0.83	0.17
	N-90	0.67	0.00	0.38
	mean	**0.80**	**0.41**	**0.28**
Moulds	N-60	4.07	4.17	4.43
	N-90	4.013	3.99	4.16
	mean	**4.11**	**4.08**	**4.30**
Total number of aerobic bacteria	N-60	7.53	6.43	6.24
	N-90	6.95	6.74	6.41
	mean	**7.14**	**6.58**	**6.32**
Enterobacteriaceae	N-60	6.15	5.42	5.07
	N-90	4.98	5.97	4.33
	mean	**5.37**	**5.69**	**4.70**
E coli 1)	N-60	4.85b	4.41a	5.60c
	N-90	-	4.93	5.16
	mean	**4.85ab**	**4.67a**	**5.38b**
*Bacillus cereus*1)	N-60	3.99ab	4.48b	3.21a
	N-90	-	4.23	4.17
	mean	**3.99**	**4.35**	**3.69**
Salmonella spp. 1)	N-60	0.0	0.0	0.0
	N-90	-	0.0	0.0
	mean	**0.0**	**0.0**	**0.0**

Source: Own work / Źródło: opracowanie własne

Explanations: as in Tab. 1

1) Evaluated only in meadow sward from the 1st cut in 2010

Table 3. Quality of grass silage from meadow fertilized with manure, liquid manure and mineral fertilizers, mean from years 2008-2010

Tab. 3. Jakość kiszonki z runi łąkowej nawożonej obornikiem, gnojówką i nawozami mineralnymi, średnie z lat 2008-2010

Examined parameter	Fertilization level	Value of parameter in grass silage from objects		
		fertilized with inorganic fertilizers	fertilized with manure	fertilized with liquide manure
Dry matter content, $g \cdot kg^{-1}$	N-60	309.5a	380.4b	330.5ab
	N-90	326.9	332.0	347.0
	mean	**319.4**	**356.7**	**338.8**
pH	N-60	4.25ab	4.35b	4.21a
	N-90	4.16b	4.40c	4.04a
	mean	**4.19a**	**4.38b**	**4.12a**
$N\text{-}NH_3$ in N tot., $g \cdot kg^{-1}$	N-60	116.2b	122.4b	85.7a
	N-90	80.3a	112.1b	80.0a
	mean	**95.7b**	**117.4c**	**82.9a**
Lactic acid content, $g \cdot kg^{-1}$ DM	N-60	41.63a	37.89a	51.36b
	N-90	56.74b	34.82a	58.00b
	mean	**50.26b**	**36.39a**	**54.68b**
Volatile fatty acids content, $g \cdot kg^{-1}$ DM	N-60	32.05ab	37.91b	29.23a
	N-90	26.31a	41.02b	19.76a
	mean	**28.77a**	**39.43b**	**24.49a**
Sum of fermentation products, $g \cdot kg^{-1}$ DM	N-60	73.68	75.80	80.59
	N-90	83.05	75.84	77.76
	mean	**79.03**	**75.82**	**79.17**
Share of lactic acid in sum of fermentation products, %	N-60	56.53ab	50.58a	62.03b
	N-90	67.88b	45.26a	74.58b
	mean	**63.01b**	**47.98a**	**68.30b**

Source: Own work / Źródło: opracowanie własne

Explanations: as in Tab. 1

Table 4. Nutritive components content in grass silage from meadow fertilized with manure, liquid manure and mineral fertilizers, mean from years 2008-2010

Tab. 4. Zawartość składników pokarmowych w kiszonkach z runi łąkowej nawożonej obornikiem, gnojówką i nawozami mineralnymi, średnie z lat 2008-2010

Examined parameter	Fertilization level	Value of parameter in grass silage from objects		
		fertilized with inorganic fertilizers	fertilized with manure	fertilized with liquide manure
Total protein, g kg^{-1} DM	N-60	123.2a	140.1b	126.9a
	N-90	128.2a	133.5b	132.7ab
	mean	**126a**	**136.8b**	**129.8a**
Crude ash, g kg^{-1} DM	N-60	83.9	85.3	84.9
	N-90	83.6a	88.3b	79.8a
	mean	**83.7ab**	**86.8b**	**82.3a**
Crude fat, g kg^{-1} DM	N-60	21.1	34.6	34.4
	N-90	35.0	33.6	35.3
	mean	**33.7**	**34.1**	**34.9**
NDF, g kg^{-1} DM	N-60	465.9	457.4	453.4
	N-90	450.6	461.5	454.9
	mean	**457.2**	**457.4**	**456.2**
ADF, g kg^{-1} DM	N-60	288.6	285.5	286.7
	N-90	283.5	283.7	297.9
	mean	**285.7**	**284.6**	**292.3**

Explanations: as in Tab. 1

Source: Own work / Źródło: opracowanie własne

Table 5. Count of individual groups of microorganisms (log·cfu g^{-1} FM) in grass silage from meadow fertilized with manure, liquid manure and mineral fertilizers, mean from years 2008-2010

Tab. 5. Liczebność poszczególnych grup mikroorganizmów (log jtk g^{-1} św. m.) w kiszonce z runi łąkowej nawożonej obornikiem, gnojówką i nawozami mineralnymi, średnie z lat 2008-2010

Examined parameter	Fertilization level	Value of parameter in grass silage from objects		
		fertilized with inorganic fertilizers	fertilized with manure	fertilized with liquide manure
Yeasts	N-60	2.48	2.22	1.94
	N-90	1.96	1.91	2.40
	mean	**2.17**	**2.06**	**2.17**
Moulds	N-60	3.76b	2.17a	3.66b
	N-90	4.50	3.58	3.77
	mean	**4.20b**	**2.87a**	**3.72ab**
Total number of aerobic bacteria	N-60	6.19	5.91	5.67
	N-90	5.69	5.94	5.43
	mean	**5.89**	**5.92**	**5.55**
Enterobacteriaceae	N-60	1.96	1.89	2.31
	N-90	1.33	2.11	1.53
	mean	**1.59**	**2.00**	**1.92**
E coli 1)	N-60	1.20	0.83	1.00
	N-90	-	1.00	1.00
	mean	1.20	**0.91**	**1.00**
*Bacillus cereus*1)	N-60	3.33	4.22	3.36
	N-90	-	3.36	3.60
	mean	3.33	**3.79**	**3.48**
Salmonella spp. 1)	N-60	0.0	0.0	0.0
	N-90	-	0.0	0.0
	mean	**0.0**	**0.0**	**0.0**

Source: Own work / Źródło: opracowanie własne

Explanations: as in Tab. 1

1) Evaluated only in meadow sward from the 1st cut in 2010

The percentage share of lactic acid in the total quantity of acids observed in this silage was also found to be the lowest, which indicates that the silage is of a lower quality. The volatile fatty acid content (acetic + butyric + propionic) in the silage samples was inversely proportional to the acetic acid content. The most significant quantities of volatile fatty acids were observed in silage from the two zones fertilized with manure (Table 3).

Levels of the majority of nutritional elements in the silage were correlated to the type of fertilizer applied. Silage made from sward fertilized with manure, like the green fodder from which it was made, contained significantly greater amounts of total protein than silage from sward fertilized with NPK fertilizers and liquid manure. The crude ash level was similar to total protein content and was greatest in silage from zones fertilized with manure. Differences in the levels of individual fibre fractions in silage from different zones were less marked (Table 4).

The type of fertilizer applied was observed to have no significant influence on the numbers of the microbes tested for in silage samples (Table 5). The abundance of yeasts in silage significantly increased in relation to the number found in ensiling green fodder and was not correlated to the form of fertilizer applied. The number of fungi, whose enzyme activity reduces the nutritional value of fodder and results in negative organoleptic change, was of a similar level in silage from sward fertilized with inorganic NPK fertilizers as in green fodder (around 10^4 CFU g dry weight of silage). Meanwhile in silage made from sward fertilized with manure and liquid manure the number of moulds was lower than in the green fodder. The total number of aerobic microbes, a fundamental though non-specific hygiene criterion indicating the microbiological state of fodder, was lower on average than in ensilaged green fodder and was found to be at a similar level in the majority of silage samples tested. The number of bacteria from the *Enterobacteriaceae* group, including *E.coli*, whose natural environment is the digestive tract of humans and animals, was significantly lower in silage than in the ensilaged green fodder, a phenomenon frequently mentioned in past research. No significant increase in microbes from the *Enterobacteriaceae* group was observed under the influence of organic fertilizers. The number of pathogenic *Bacillus cereus* bacteria in silage was lower on average than in the green fodder set aside for ensilaging. *Salmonella* spp. bacteria were not found in any of the silage samples.

4. Discussion

To summarise, the results of this assessment of the impact of organic fertilizers on the microbiological quality and nutritional value of silage made from sward show that the application of organic fertilizers had a significant impact on the chemical composition of sward and the quality of the silage that can be produced from it. Sward fertilized with manure was characterised by higher levels of total protein, crude ash and all fibre fractions than those contained in sward fertilized with inorganic NPK fertilizer and liquid manure. Similar relations in content of nutrients were stated in obtained silages.

Nevertheless, a lower sugars content was observed in sward from zones fertilized with manure, as well as a lower sugar to protein ratio, which indicates that it is a less suitable plant material for ensilage [14]. The chemical composition of sward fertilized with liquid manure was similar to the composition of sward from zones fertilized with inorganic NPK fertilizer, as reported in previously study [11-13]. A lower sugars level in meadow sward fertilized with manure was also observed by Kacorzyk and Szewczyk. [15] They explained the phenomenon as the effect of the accumulation of a large number of ammonium ions in soil as a result of ammonification. On absorption by plants ammonium nitrogen is subject to nitrate reduction, which is accompanied by the release of energy and a reduction in sugars levels. [16]

Use of inorganic fertilizers sometimes produced lower pH and higher content of lactic acid in silage, compared with using organic fertilizers [17]. In present study the type of fertilizer was strongly correlated to the majority of parameters involved in the chemical analysis of silage. Silage made from sward fertilized with manure, regardless of the dose of fertilizer applied, was marked by a significantly higher pH, a higher level of ammonia in the total nitrogen, a greater level of volatile fatty acids and a smaller share of lactic acid in the total acids. This indicates that silage produced from sward fertilized with manure is of a significantly lower quality. The quality of silage from sward fertilized with fermented urine was close to the quality of sward fertilized with inorganic fertilizer, which was also previously reported by authors [11-13].

No significant increase in the number of individual microbes was observed in silage as a result of fertilization of sward with organic fertilizers. Nevertheless the number of bacteria of the *Enterobacteriaceae* group in all silage samples and moulds in the majority of silage samples from zones fertilized with organic fertilizer was even lower than in sward. This confirms the hypothesis that is possible for lactic fermentation bacteria in biotechnological processes to inhibit the growth of pathogenic bacteria and moulds [18, 19]. It is also confirmation of earlier results from tests indicating that the ensilage process can restrict the number of pathogenic bacteria in silage [11-13]. As shown in the research of Zielińska et al [8, 19] the microbiological quality of silage made from sward fertilized with organic fertilizer can be improved by ensilaging with starter cultures of bacteria capable of inhibiting the growth of pathogenic bacteria.

5. Conclusions

The assessment of silage demonstrates the significant influence of fertilization with organic fertilizers on selected parameters of chemical analysis and the nutritional value of silage.

Sward from zones fertilized with manure represents a worse ensilaging material (poor sugar / protein ratio) than sward fertilized with inorganic fertilizer and liquid manure. Therefore the fertilization of sward with manure will, as a rule, hinder the ensilage process and significantly reduce the quality of the end product. Fertilization with liquid manure yields fodder with a nutritional value close to fodder from zones fertilized with inorganic fertilizer and at the same time does not inhibit the fermentation process, which yields a very good quality silage from sward fertilized with this type of fertilizer.

Fertilization with organic fertilizer, in keeping with recommendations about the timers and dosages for the application of these fertilizers on permanent grasslands, does not increase the microbial contamination of the resulting fodder.

At the same time it was shown that the process of preserving sward through ensilage can be an effective means of inhibiting the spread of pathogenic bacteria in silage.

6. References

[1] Jankowska-Huflejt H., Barszczewski J.: Podstawy nawożenia łąk w gospodarstwach ekologicznych. W: Poradnik Rolnika Ekologicznego. Monografia pod redakcją Karola Węglarzy. Wyd. Zakład Doświadczalny Instytutu Zootechniki PIB Grodziec Śląski Sp. z o.o., 2014: 32-45.

[2] Jankowska-Huflejt H.: Wytyczne nawożenia łąk w gospodarstwach ekologicznych. Materiały instruktażowe/Procedury, nr 119/3, Wyd. IMUZ, Falenty, 2008, 20 pp.

[3] Wesołowski P.: Nawożenie łąk nawozami naturalnymi w świetle doświadczeń Zachodniopomorskiego Ośrodka Ba-

dawczego IMUZ w Szczecinie. Falenty. Wydaw. IMUZ, 2008, ISBN 978-83-88763-74-8, 56 pp.
[4] Dach J.: Kompostowanie obornika i dlaczego warto to wdrażać? Bydło, 2006, nr 1, s. 16.
[5] Jankowska-Huflejt H.: Ocena wpływu wieloletniego nawożenia obornikiem na stan i produkcyjność łąki. Rozpr. dokt. Biblioteka IMUZ, Falenty, 1998, 115 pp.
[6] Ustawa o nawozach i nawożeniu z dnia 10 lipca 2007 r.. Dz. U. Nr 147 poz. 1033, z późniejszymi zmianami.
[7] Purwin C., Lipiński K., Pysera B.: Jakość higieniczna kiszonek. Życie Weterynaryjne, 2012, Nr 1: 37-40.
[8] Zielińska K., Kapturowska A.U., Stecka K., Kupryś-Caruk M.P., Miecznikowski A.H.: Ocena stopnia skażenia bakteriami potencjalnie patogennymi kiszonek z runi łąkowej. Journal of Research and Applications in Agricultural Engineering, 2012, vol. 57 (4): 217-222.
[9] Zielińska K., Stecka K., Kupryś M., Kapturowska A.U., Miecznikowski A.H.: Ocena stopnia skażenia bakteriami potencjalnie patogennymi runi łąkowej i gleb nawożonych płynnymi nawozami organicznymi. Journal of Research and Applications in Agricultural Engineering, 2011, vol. 56 (4): 212-215.
[10] GUS: Produkcja upraw rolniczych i ogrodniczych w 2011 r. Materiały źródłowe. Warszawa. 2012. ISSN 1509-7099, 124.
[11] Jankowska-Huflejt H., Wróbel B.: Wpływ wiosennego nawożenia obornikiem i gnojówką na plony i jakość pokarmową oraz mikrobiologiczną kiszonki z runi łąkowej w warunkach gospodarowania ekologicznego. Journal of Research and Applications in Agricultural Engineering, 2011, Vol. 56. Nr. 3: 164-170.
[12] Wróbel B., Jankowska-Huflejt H.: The influence of natural fertilization on quality and nutritive value of grass silage. Grassland Science in Europe, 2010, vol. 15: 581-583.
[13] Wróbel B., Zielińska K., Fabiszewska A.: Wpływ nawożenia gnojówką bydlęcą na jakość runi łąkowej i jej przydatność do zakiszania. Problemy Inżynierii Rolniczej, 2013, z. 2 (80): 151-164.
[14] McDonald P., Henderson A.R., Heron S.J.E.: The biochemistry of silage. Bucks. Chalcombe Publications, 1991, 340 pp.
[15] Kacorzyk P., Szewczyk W.: Wpływ nawożenia na zawartość składników organicznych oraz makroelementów w wybranych grupach roślin łąkowych. Łąkarstwo w Polsce, 2008, nr 11: 77-85.
[16] Barabasz W.: Mikrobiologiczne przemiany azotu glebowego. II. Biotransformacja azotu glebowego. Postępy Mikrobiologii, 1991, XXXI. z. 1: 3-33.
[17] Muller C.E., Johansson M., Salomonsson A.C., Albihn A.: Effect of anaerobic digestion residue vs. livestock manure and inorganic fertilizer on the hygienic quality of silage and haylage in bales. Grass and Forage Science, 2013, 69, 74-89.
[18] Davies D.R., Merry R.J., Bakewell E.L.: The effect of timing of slurry application on the microflora of grass, and changes occurring during silage fermentation. Grass and Forage Science, 1996, vol. 51, 42-51.
[19] Zielińska K., Fabiszewska A., Stecka K., Wróbel B.: Rola bakterii fermentacji mlekowej w poprawie jakości mikrobiologicznej kiszonek z runi łąkowej w gospodarstwach ekologicznych. Woda-Środowisko-Obszary Wiejskie, 2013, t. 13 z. 1 (41), 171-182.