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EVALUATION OF LACTATIONAL EXCRETION OF UREA AND AMMONIA IN DAIRY CATTLE HERDS

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SUMMARY

The aim of the study was to evaluate the lactational unit production of urea and ammonia emissions from cows kept in eastern Poland. The study covered 1089 lactations of Polish Holstein-Friesian cows born between 1992 and 2018 in 15 cattle herds located in the Masovian and Podlaskie Voivodeships. The amount of urea excreted in the urine and nitrogen compounds in the faeces was calculated based on the following regression equations: (y = 15.46 × urea concentration in milk (g/L) + 193.4); y = 11.42 × urea concentration in milk (g/L) + 41.93); y = 4.05 × urea concentration in milk (g/L) + 151.47). Several factors affecting the total production of urea were examined: four groups of animals were distinguished according to their milk yield in 305-day lactation; three groups based on year of birth; four age groups; and three groups according to urea content in milk. The results of the study showed that the average concentration of urea in cow urine was 78.6 kg, and the ammonia emission from a lactating cow was 44.6 kg. The study demonstrated large variation in the amount of nitrogen compounds excreted in faeces and the degree of ammonia emission risk among animals. The main factors differentiating the amount of nitrogen compounds in the urine and faeces and the level of ammonia emission into the atmosphere included the cow's production level, its year of birth, and urea content in milk. These results can be used to assess the potential risk of ammonia emissions from dairy cattle farming to the environment. The data obtained in the study, in addition to their pure scientific value, can serve as a source of information for national centres responsible for monitoring and assessing the threat of ammonia emissions to the environment.

KEY WORDS: dairy cows, urea in milk, ammonia emission

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INTRODUCTION

Urea is an organic chemical compound that is the end product of protein metabolism in cows. It is formed in the liver through the urea cycle from ammonia generated as a result of amino acid and protein catabolism. It is mainly excreted from the body through waste, i.e. urine and faeces, but also appears in the milk of cows. The nitrogen concentration in cow urine ranges from 6.8 to 21.6 g/L, with urea representing an average of 69% of that nitrogen (Bristow et al., 1992). Excreted urea is hydrolysed by microorganisms producing urease, which converts it to ammonium carbonate. The ammonium ion then dissociates into ammonia gas and carbon dioxide. Ammonia (NH_3) is a colourless, irritating gas compound of hydrogen and nitrogen which is highly soluble in water. The presence of ammonium nitrogen in surface water is commonly associated with agricultural pollution. Excess ammonia can damage plants and is extremely toxic to aquatic organisms, especially at elevated pH and temperature levels.

The digestibility coefficients of nitrogen compounds in dairy cows are not high. Dairy cows excrete an average of 25% to 35% of the nitrogen they consume in their milk, and the remainder of the undigested nitrogen compounds is excreted in urine and faeces (Bougouin et al., 2022). About 60% to 80% of the nitrogen contained in feed for cows is excreted, mainly in the urine (Kebreab et al., 2001). The main source of ammonia is urea nitrogen present in animal waste, i.e. urine and faeces. The excreted urea is hydrolysed to ammonia and carbon dioxide by the activity of urease-producing microorganisms in faeces. From 100 g of urea, 74.7 dm^3 or ≈ 56.8 g of ammonia can be obtained through this process. The negative effects of ammonia (NH_3) in the environment are associated with the formation of acid rain, eutrophication of soil and surface waters, and the formation of fine particulate matter ($PM_{2.5}$). According to Bauer et al. (2016) and Erisman and Schaap (2004), agriculture is responsible for 30% of $PM_{2.5}$ fine particulate matter emissions in the US and 50% in Europe. Excessive levels of nitrogen compounds can lead to numerous problems with surface waters, including the growth of algae, which causes water deoxygenation. In humans, nitrates present in drinking water can lead to the formation of methaemoglobin, which limits the availability of oxygen in the blood, leading to serious health consequences, which may be life-threatening.

The concentration of urea in urine is the most important predictor of ammonia emissions from dairy cows (Hristov et al., 2011). It should be emphasized that urine and faeces separately emit minimal amounts of ammonia. Ammonia emission processes intensify when urine and faeces are physically combined in livestock buildings. In practice, a number of factors affect the rate of ammonia release in cattle herds. Those most commonly listed in the specialist literature are temperature, air velocity, pH, surface area of faeces and urine deposition, manure moisture, and storage time. Factors with a particularly strong impact on the intensity of ammonia emissions into the atmosphere include increased manure pH and increasing temperature (Wyer et al., 2022).

According to Draaijers et al. (1989) and Howarth et al. (1996), nitrogen excretion by dairy cattle should be reduced due to the global impact of agriculture on environmental pollution with nitrogen compounds (N_2O, NO, and NO_2), particularly the release of ammonia into the atmosphere and the leaching of nitrates into surface water and groundwater. Van Duinkerken et al. (2011a) and Van Duinkerken et al. (2011b) reported that an agreement was reached in the Netherlands between the Dutch government and dairy farmers to reduce the urea concentration in milk to 200 mg per litre, with the aim of protecting the natural environment. In return, Dutch farmers were exempted from the obligation to invest in systems that maintain low ammonia emissions.

The issue of ammonia emissions to the environment is regulated by EU law. Within the EU, the National Emissions Ceilings (NEC) Directive (2016/2284; European Union, 2016) requires member states to report NH_3 emissions and monitor its concentration in sensitive habitats, while the Habitat Directive (92/43/EEC) requires that projects be implemented in a way that minimizes their negative impact on sensitive habitats. In Poland, the deposition of natural fertilizers on available land cannot exceed 170 kg N/ha/year in open systems and in systems using buildings with unrestricted animal movement on unhardened surfaces that are neither pasture nor hardened runways (Council of Ministers Regulation 2023).

The aim of the study was to evaluate the lactational unit production of urea and ammonia emissions from cows kept under the conditions of eastern Poland.

MATERIAL AND METHODS

The study covered 1089 lactations of Polish Holstein-Friesian cows born between 1992 and 2018, kept in 15 cattle herds located in the Masovian and Podlaskie Voivodeships in eastern Poland. The data used in the study pertained to herds evaluated for milk yield performance. Measurement of milk urea in all months of lactation was a condition for inclusion of the lactation in the calculations. The average size of the herds was approximately 35 cows, so that the average number of lactations per cow was about 2.1. Data on actual milk yield levels in 305-day lactation are presented in Table 1. Urea yield and ammonia emission levels were calculated for each month of lactation, taking into account the level of urea in the milk and the milk yield of the cows. The animals were fed diets with varying levels of protein and energy balance: 350 cows received fully balanced diets, 84 cows received diets with insufficient protein levels, and 110 cows received diets with excessive protein levels.

The population was differentiated based on the following factors: milk yield in 305-day lactation (≤6 000; 6 000–8 000; 8000–10 000; >10 000 kg); cows' year of birth (1992–2000; 2000–2010; 2010–2018); cows' age expressed as lactation number (first lactation; second lactation; third lactation; lactations from 4 to 12) and urea content in milk (1–150; 150–250; >250 mg/L). The initial goal of the study was to determine the level of periodic and lactational urea production in the milk. This was used to determine the level of urea and other nitrogen compounds in the cows' excreta, i.e. urine and faeces, in the same production periods. The final element of the research was assessment of the total production of nitrogen compounds in milk and cow excreta during lactation. The amounts of urea excreted in the urine and nitrogen compounds in the faeces were calculated based on the following regression equations (Zhai et al., 2005):

y (total nitrogen excretion) = 15.46 × urea concentration in milk (g/L) + 193.4
y (total urinary nitrogen) = 11,42 × urea concentration in milk (g/L) + 41.93
y (faecal nitrogen) = 4,05 × urea concentration in milk (g/L) +151.47

For the calculation of ammonia emissions from cow urine, it was assumed that 100 g of urea produces 56.8 dm^3 of ammonia through enzymatic hydrolysis, and that the molar mass of ammonia is 17.03 g/mol.

Detailed data on the number of animals and records within each group are presented in Table 1.

The following linear model including the effects of lactation milk yield group, birth year group, age (lactation) group, and urea milk content group was used:

$$y_{ijklmn} = \mu + A_i + B_j + C_k + D_l + F_m + (AB)_{ij} + (AC)_{ik} + (AD)_{il} + e_{ijklmn};$$

where:

y_{ijklmn} – value of trait
μ – grand mean
A_i – fixed effect of lactation milk yield group (i = 1, 2, 3, 4)
B_j – fixed effect of birth year group (j = 1, 2, 3)
C_k – fixed effect of age (lactation) group (k = 1, 2, 3, 4)
D_l – fixed effect of milk urea content group (l = 1, 2, 3)
F_m – random effect of cow (I = 1, 2, 3,…, 544)
$(AB)_{ij}$ – effect of interaction between lactation milk yield group × birth year group
$(AC)_{ik}$ – effect of interaction between lactation milk yield group × cow age group
$(AD)_{il}$ – effect of interaction between lactation milk yield group × milk urea content group
e_{ijklmn} – sampling error

The results were statistically processed by multivariate analysis of variance with the least squares method. Significance of differences between means was estimated with the Duncan test at $P \leq 0.01$. The GLM and FREQ procedures of the SAS statistics software package (SAS Institute, 2008) were used for the calculations.

RESULTS

The average milk yield in 1089 completed lactations was 7 290 kg (Table 1). The cows' year of birth and the level of urea in the milk was shown to significantly influence the milk yield in the cow population. The highest milk yield was observed in cows in lactations from 4 to 12 and those whose milk contained over 250 mg/L of urea. They produced 7795 and 7 910 kg of milk, respectively, in 305-day lactation. Analysis of the influence of production level showed varied milk yields among that the population, ranging from 4 800 kg (for the lowest production group ≤6000 kg) to 10 913 kg (for the highest production group >10 000 kg). The significant variability of actual milk yield in the population was confirmed by the high coefficient of variation for this trait: v = 29%.

Table 1

The impact of selected factors on actual milk yield in 305-day lactation, kg

Factor	Milk yield in 305-day lactation, kg				Total
	≤6000	6000-8000	8000-10 000	>10 000	
	Number of observations Mean ± SD				
Year of birth					
1992-2000	63	55	43	20	181
	4 918 ± 868	7 005 ± 567	8 924 ± 540	10 942 ± 821	7 170 ^{B} ± 2 143
2000-2010	186	230	119	39	574
	4 950 ± 812	6 894 ± 589	8 845 ± 529	10 854 ± 914	6 938 ^{C} ± 1 883
2010-2018	52	106	121	55	334
	4 118 ± 1687	7 164 ± 577	8 954 ± 548	10 944 ± 862	7 961 ^{A} ± 2 260
Number of completed lactation					
1	136	134	78	11	359
	4 754 ± 900	7 002 ± 586	8 788 ± 532	11 075 ± 945	6 663 ^{D} ± 1 878
2	78	110	77	35	300
	4 886 ± 1 126	6 987 ± 651	8 995 ± 557	10 910 ± 860	7 414 ^{C} ± 2 110
3	29	83	59	26	197
	4 456 ± 1 437	6 891 ± 570	8 956 ± 528	10 642 ± 473	7 646 ^{B} ± 1 999
4-12	58	64	69	42	233
	4 962 ± 1 129	7 056 ± 525	8 888 ± 524	11 040 ± 1 016	7 795 ^{A} ± 2 252
Urea level in milk, mg/L					
1-150	65	52	37	14	168
	4 702 ± 1 128	6 886 ± 602	8 786 ± 568	10 699 ± 562	6 777 ^{C} ± 2 134
150-250	201	258	183	59	701
	4 873 ± 1 003	7 001 ± 585	8 952 ± 527	10 780 ± 667	7 218 ^{B} ± 1 994
>250	35	81	63	41	220
	4 561 ± 1 292	6 987 ± 611	8 833 ± 547	11 177 ± 1 123	7 910 ^{A} ± 2 250
Total	301	391	283	114	1089
	4 800 ^{4} ± 1 070	6 983 ^{3} ± 593	8 904 ^{2} ± 540	10 913 ^{1} ± 867	7 290 ± 2 097

Means in columns within factors with different superscript letters differ significantly at $P \leq 0.05$.

Means within a row with different superscript numbers differ significantly at $P \leq 0.05$.

The results indicated that the average lactational yield of urea in the milk and urine of cows was 1.6 kg and 78.6 kg, respectively (Table 2). The standard deviations indicated very high variability of these characteristics, with coefficients of variation of 69% and 39%, respectively. These data suggest that in dairy cattle herds under the conditions of eastern Poland, emissions of nitrogen compounds, mainly urea, were highly diverse and strongly influenced by various environmental factors. Analysis of the data from Table 2 shows that the main factors differentiating the emission levels of nitrogen compounds in dairy cattle herds in eastern Poland include the production level (linked to the level of nutrition) and the milk urea concentration (dependent mainly on the protein level in the diet). A more than 3-fold increase in the yield of urea in milk during lactation was noted between animals with the lowest (1.1 kg) and highest production levels (3.4 kg). A systematic increase in the lactational yield of urea in the urine was also observed in cows as the production level increased. For example, animals with the lowest production level (≤6000 kg) produced 60.1 kg of urea during lactation, while their counterparts with the highest production level produced 51.8 kg more. A significant increase in the yield of urea was also observed in cows producing milk with the highest urea concentration (>250 mg/L). The yield of urea in the milk and urine of these cows was higher by 1.1 kg and 44.6 kg, respectively, compared to animals producing milk with the lowest urea concentration (<150 mg/L). The analysis taking into account the cows' year of birth also demonstrated a significant increase in urea production in the milk and urine in later years of birth. The data indicated an increase in excretion of urea in the milk and urine, amounting to 1 kg and 24 kg, respectively, in cows born in the years 2010–2018 relative to the years 1992–2000.

Table 2

The impact of selected factors on lactational yield of urea in milk and urine and the level of nitrogen compounds in cow faeces, kg

Factor	**Milk yield in 305-day lactation, kg**				Total
	≤6000	**6000-8000**	**8000-10 000**	**>10 000**	
			Mean ± SD		
Year of birth					
			Milk		
1992-2000	0.8 ± 0.5	0.8 ± 0.5	1.3 ± 0.5	2.2 ± 0.8	1.1 ^{C} ± 0.7
2000-2010	0.9 ± 0.5	1.3 ± 0.6	1.7 ± 0.9	2.9 ± 1.4	1.4 ^{B} ± 0.9
2010-2018	1.1 ± 0.7	1.6 ± 0.6	2.4 ± 1.2	3.4 ± 1.6	2.1 ^{A} ± 1.3
			Urine		
1992-2000	59.5 ± 25.9	62.9 ± 26.8	69.1 ± 21.8	79.1 ± 22.9	64.9 ^{C} ± 25.5
2000-2010	69.4 ± 23.6	78.3 ± 24.1	78.6 ± 27.9	97.9 ± 30.7	76.8 ^{B} ± 26.2
2010-2018	60.1 ± 28.3	82.6 ± 37.4	96.5 ± 29.6	111.9 ± 36.5	88.9 ^{A} ± 36.7
			Faeces		
1992-2000	54.3 ± 21.2	54.8 ± 23.1	60.4 ± 17.8	69.5 ± 16.3	57.6 ^{C} ± 21.0
2000-2010	60.3 ± 17.4	66.9 ± 18.9	65.4 ± 19.8	78.8 ± 17.8	65.3 ^{B} ± 19.1
2010-2018	50.5 ± 22.4	64.5 ± 19.8	74.8 ± 19.7	84.6 ± 23.6	69.3 ^{A} ± 23.3
Number of completed lactation					
			Milk		
1	1.1 ± 0.6	1.5 ± 0.7	2.3 ± 1.4	4.8 ± 1.9	1.6 ^{A} ± 1.2
2	0.8 ± 0.4	1.3 ± 0.6	1.8 ± 0.9	2.8 ± 1.5	1.5 ^{B} ± 0.9
3	0.8 ± 0.5	1.3 ± 0.6	1.9 ± 0.9	2.3 ± 0.9	1.6 ^{AB} ± 0.9
4-12	0.9 ± 0.5	1.3 ± 0.6	1.8 ± 0.8	3.1 ± 1.2	1.7 ^{A} ± 1.1
			Urine		
1	70.9 ± 25.3	82.2 ± 35.7	90.2 ± 36.9	141.1 ± 40.2	81.5 ^{A} ± 34.9
2	61.2 ± 22.9	75.1 ± 26.4	78.7 ± 25.9	97.1 ± 36.9	74.9 ^{B} ± 28.7
3	60.3 ± 25.0	73.2 ± 23.6	88.6 ± 30.5	87.2 ± 26.1	77.7^{AB} ± 28.1
4-12	62.3 ± 26.9	75.9 ± 24.2	82.3 ± 21.5	103.4 ± 27.6	79.4 ^{A} ± 28.1

			Faeces		
1	60.9 ± 18.7	66.8 ± 22.1	70.1 ± 25.7	101.3 ± 25.9	66.4^{A} ± 22.9
2	54.6 ± 18.6	63.1 ± 19.4	65.3 ± 18.9	77.9 ± 23.8	63.2^{B} ± 20.7
3	52.0 ± 20.5	63.1 ± 19.3	70.2 ± 18.3	71.1 ± 16.5	64.7^{AB} ± 19.8
4-12	55.3 ± 21.2	64.1 ± 18.1	69.4 ± 15.7	81.5 ± 16.1	66.6^{A} ± 26.6
Urea level in milk, mg/L					
			Milk		
1-150	0.7 ± 0.4	0.9 ± 0.5	1.4 ± 0.8	1.9 ± 0.8	1.1^{C} ± 0.7
150-250	0.9 ± 0.5	1.3 ± 0.6	1.9 ± 0.8	2.7 ± 1.2	1.5^{B} ± 0.9
>250	1.2 ± 0.5	1.5 ± 0.7	2.6 ± 1.5	3.8 ± 1.6	2.2^{A} ± 1.5
			Urine		
1-150	49.1 ± 19.1	59.8 ± 19.8	62.9 ± 21.2	66.6 ± 17.1	56.9^{C} ± 20.5
150-250	68.4 ± 23.4	75.8 ± 21.7	81.4 ± 23.1	92.7 ± 26.8	76.6^{B} ± 23.9
>250	81.1 ± 30.4	93.2 ± 44.1	107.7 ± 36.4	125.8 ± 32.7	101.5^{A} ± 40.5
			Faeces		
1-150	51.9 ± 18.6	61.47 ± 19.4	63.2 ± 19.1	67.3 ± 12.6	58.6^{C} ± 19.2
150-250	58.9 ± 19.2	64.37 ± 18.3	67.1 ± 17.8	76.5 ± 18.6	64.6^{B} ± 19.0
>250	58.2 ± 21.7	67.02 ± 25.6	76.4 ± 25.1	89.3 ± 23.5	72.5^{A} ± 26.3
Total					
Milk	0.9^{4} ± 0.5	1.3^{3} ± 0.6	1.9^{2} ± 1.1	3.00^{1} ± 1.5	1.6 ± 1.1
Urine	65.7^{4} ± 25.3	77.3^{3} ± 29.3	84.8^{2} ± 29.7	101.4^{1} ± 34.4	78.6 ± 30.8
Faeces	57.4^{4} ± 19.5	64.53^{3} ±20.2	68.7^{2} ± 20.2	79.9^{1} ±21.2	65.2 ± 21.1

Means in columns within factors with different superscript letters differ significantly at $P \leq 0.05$.

Means within a row with different superscript numbers differ significantly at $P \leq 0.05$.

The total yield of nitrogen-containing compounds in the milk, urine, and faeces of cows was 145.4 kg. The study showed a highly significant impact of the production level, year of cow's birth, and level of urea in milk on the amount of nitrogen compounds produced during lactation (Table 3).

Table 3
The impact of selected factors on the total yield of nitrogen compounds excreted during lactation in cow milk and faeces, kg

Factor	Milk yield in 305-day lactation, kg				Total
	≤6 000	6 000-8 000	8 000-10 000	>10 000	
	Mean ± SD				Mean ± SD Min. - Max.
Year of birth					
1992-2000	114.5 ± 46.8	118.6 ± 49.6	130.8 ± 38.9	150.8 ± 38.6	$123.6^{C} \pm 46.2$ 10.9 - 243.3
2000-2010	130.7 ± 40.6	146.49 ± 42.7	145.78 ± 47.5	179.7 ± 49.3	$143.5^{B} \pm 45.1$ 13.3 - 315.7
2010-2018	111.6 ± 50.8	148.6 ± 56.6	173.7 ± 49.9	199.8 ± 61.1	$160.4^{A} \pm 60.3$ 11.5 - 544.1
Number of completed lactation					
1	132.9 ± 43.7	150.5 ± 56.6	162.6 ± 63.4	247.3 ± 67.6	$149.4^{A} \pm 57.8$ 10.9 - 544.1
2	116.6 ± 41.1	139.5 ± 45.5	145.8 ± 44.8	177.8 ± 61.5	$139.6^{B} \pm 49.5$ 11.1 - 316.5
3	113.1 ± 45.2	137.5 ± 42.9	160.8 ± 48.8	160.6 ± 42.4	$143.9^{AB} \pm 47.7$ 11.7 - 315.7
4-12	118.5 ± 47.8	141.2 ± 42.1	153.5 ± 36.9	187.9 ± 43.9	$147.6^{A} \pm 48.1$ 12.9 - 290.3
Urea level in milk, mg/L					
1-150	101.6 ± 37.8	122.2 ± 39.4	127.5 ± 40.	135.8 ± 30.1	$116.6^{C} \pm 40.1$ 10.9 - 230.6
150-250	128.3 ± 42.7	141.5 ± 40.1	150.3 ± 41.2	171.8 ± 46.1	$142.6^{B} \pm 43.3$ 12.9 - 290.3
>250	140.5 ± 52.4	161.8 ± 69.1	186.7 ± 62.5	218.9 ± 57.4	$176.2^{A} \pm 67.3$ 17.5 - 544.1
Total	$123.9^{4} \pm 44.5$	$143.1^{3} \pm 48.7$	$155.4^{2} \pm 50.1$	$184.3^{1} \pm 56.3$	145.4 ± 51.9 10.9 - 544.1

Means in columns within factors with different superscript letters differ significantly at $P \leq 0.05$.
Means within a row with different superscript numbers differ significantly at $P \leq 0.05$.

The data in Table 4 show that the levels of nitrogen compounds present in the milk, urine, and faeces of the cow population of eastern Poland were 1.1%, 53.6%, and 45.3%, respectively. The results confirmed that the predominant route of removal of unused nitrogen compounds from the bodies of dairy cows was through their urine and faeces, while about 1.1% of the total undigested nitrogen compounds were removed in the milk.

Table 4
The percentage of nitrogen compounds excreted in milk and faeces during cows' lactation

Factor	Number of observations	Milk	Urine	Faeces	Total, %
Year of birth					
1992-2000	181	0.8	52.4	46.8	100
2000-2010	574	0.9	53.2	45.9	100
2010-2018	334	1.2	54.9	43.9	100
Milk yield in 305-day lactation, kg					
≤6 000	301	0.8	52.6	46.6	100
6 000-8 000	391	0.9	53.7	45.4	100
8 000-10 000	283	1.2	54.2	44.6	100
>10 000	114	1.6	54.4	44.0	100
Number of completed lactation					
1	359	1.1	54.0	44.9	100
2	300	0.9	53.3	45.8	100
3	197	1.1	53.6	45.4	100
4-12	233	1.1	53.3	45.6	100
Urea level in milk, mg/L					
1-150	168	0.8	48.6	50.6	100
150-250	701	1.0	53.6	45.4	100
>250	220	1.2	57.5	41.3	100
Total	1089	1,1	53,6	45,3	100

One of the main goals of this study was to estimate ammonia emissions from dairy cattle herds. The data in Table 5 show that the average amount of ammonia emissions per lactating cow was 44.6 kg. The results indicate high variability in ammonia emissions in dairy cattle herds. The main factors shown to increase the level of ammonia emissions into the atmosphere were the production level and the urea concentration in the milk. The ammonia emissions from cows with the highest production level (>10 000 kg) and those producing milk with the highest urea concentration (>250 mg/L) were higher by 20.2 kg and 25.4 kg, respectively, compared to cows with the lowest production level (≤6000 kg) and those producing milk with the lowest urea concentration.

Table 5
The impact of selected factors on the level of ammonia emissions from urea excreted in cow urine during lactation, kg per animal

Factor	Number of observations	Urea in urine, kg	Ammonia in urine, kg
Year of birth			
1992-2000	181	65.0 ^{C}	36.9
2000-2010	574	76.8 ^{B}	43.6
2010-2018	334	88.9 ^{A}	50.5
Milk yield in 305-day lactation, kg			
≤6 000	301	65.7 ^{D}	37.3
6 000-8000	391	77.3 ^{C}	43.9
8 000-10 000	283	84.8 ^{B}	48.1
>10 000	114	101.4 ^{A}	57.5
Number of completed lactation			
1	359	81.5 ^{A}	46.3
2	300	75.0 ^{B}	42.6
3	197	77.7 ^{AB}	44.1
4-12	233	79.4 ^{A}	45.1
Urea level in milk, mg/L			
1-150	168	56.9 ^{C}	32.3
150-250	701	76.6 ^{B}	43.5
>250	220	101.5 ^{A}	57.7
Total	1089	78.6	44.6

Means in columns within factors with different superscript letters differ significantly at $P < 0.05$.

DISCUSSION

In the era of climate change, the issue of nitrogen compound emissions from agriculture is at the forefront of interest for many countries worldwide. Agriculture is estimated to be responsible for over 92% of these emissions in the European Union, and 94% in Poland (Bebkiewicz et al., 2019).

According to Bieńkowski (2010), the total average annual ammonia emissions from agriculture in Poland in the early 21st century amounted to about 386,000 tonnes, with emissions from cattle manure accounting for approximately 155 000 tons. Dębski et al. (2018) reported that the total emissions of nitrogen dioxide (NO_2) and ammonia (NH_3) in Poland in 2016 were 726 400 and 267 100 tonnes, respectively. According to these authors, the agricultural sector is the main source of ammonia emissions (98%), mainly due to the size of livestock populations and the use of mineral fertilizers. Farm animals are considered the main contributors to NH_3 emissions; for instance, they account for 50% of NH_3 emissions in the United States (Hristov et al., 2011). In Poland, the largest NH_3 emissions from animal production were linked to cattle production. The annual mean for this group of animals was 116.5 $Gg \cdot year^{-1}$, which was about 68% higher than for pigs – 67.9 $Gg \cdot year^{-1}$ (Mielcarek-Bocheńska and Rzeźnik, 2018). According to Bebkiewicz et al. (2019), the main sources of ammonia in the environment are manure management and the use of mineral nitrogen fertilizers, contributing 78% and 22%, respectively. Dębski et al. (2018) estimated the unit emissions of ammonia and nitrogen dioxide from livestock species used in Poland and reported that dairy cows emitted an average of 29.1 kg of ammonia and 0.27 kg of nitrogen dioxide per head per year in 2016.

According to Dammgen et al. (2009), a cow in the Netherlands emits about 40 kg of ammonia to the atmosphere annually. The results of scientific studies indicate that the amount of nitrogen excreted in the urine and faeces of cows (kg/year) is closely linked to the level of urea in their milk. Similarly, Guliński et al. (2016) reported that as the concentration of urea in cow milk increased from 100 to 300 mg/L, the amount of urea nitrogen excreted with the urine increased from 45.8 to 137.3 kg/year. Szarkowski et al. (2009) pointed out the lack of balanced energy and protein in the diet of cows as the main cause of excessive nitrogen excretion into the environment.

Cattle housing varies around the world. Cattle can be kept in buildings with slatted floors and manure pits below, on solid floors, or in individual stalls (Robbins et al., 2019; Wang et al., 2018). Moreover, cattle can be housed in buildings with natural ventilation year round or only in winter, with grazing periods in summer (McIlroy et al., 2019). Changes to the housing environment, including ventilation rates, bedding, flooring, temperature, and manure storage, can help to reduce emissions from this source. A common slurry-based system can be made less harmful by introducing straw bedding, which reduces NH_3 emissions by up to 30% (Webb et al., 2005). Another highly effective way to reduce NH_3 emissions from manure storage is to install covers and roofs, which can reduce emissions by up to 80% (Webb et al., 2005). Thus opportunities to reduce global ammonia emissions to lessen the environmental burden are associated with various aspects of cattle management. Some recommendations mentioned by Wang et al. (2018) and Webb et al. (2005) involve improving dairy cow performance and herd structure (reducing the number of animals), combining different manure management systems, and rapidly incorporating organic fertilizers into arable land. One of the newest ways to reduce ammonia emissions from dairy cattle is to install special toilets for cows (Dirksen et al., 2020). This innovation, first implemented in the Netherlands, has shown extremely promising results and may be a breakthrough in reducing ammonia emissions from dairy cattle herds.

CONCLUSION

The results of our own research have shown that the average ammonia emissions from a lactating cow amounted to 44.6 kg. The study demonstrated significant variation in the amount of nitrogen compounds excreted in the faeces and urine among animals, as well as in the level of methane emissions. The main factors that differentiate the amounts of nitrogen compounds in the urine and faeces, as well as the level of ammonia emissions into the atmosphere, include the level of production, year of birth, and level of urea in milk. The study found that these factors have a statistically significant impact on the parameters analysed. This means that discussions of the scale of ammonia emissions from dairy cattle herds in Poland should take into account the determinants and dependencies identified in this study. The data obtained in the study, in addition to their pure scientific value, can serve as a source of information for national centres responsible for monitoring and assessing the threat of ammonia emissions to the environment.

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