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Josip Juraj Strossmayer University of Osijek
Faculty of Agrobiotechnical Sciences Osijek
Vladimira Preloga 1
31000 Osijek
Croatia

Precision farming – estimation of ammonium pollution from dairy cattle farms

Vesna Gantner[1], Božidarka Marković[2], Zvonimir Steiner[1], Mirna Gavran[1], Dragan Dokić[3]

[1]Faculty of Agrobiotechnology Osijek, University of Josip Juraj Strossmayer in Osijek, Osijek, Croatia
[2] Biotechnical Faculty, University of Montenegro, Podgorica, Montenegro
[3] Erdut Municipality, Dalj, Croatia
**Correspondence: vgantner@fazos.hr*

Introduction

Precision dairy farming is one of the major topics that influences dairy farming developments world-wide. Precision dairy farming implies the use of various technologies to measure: physiological, behavioral, and production indicators on individual animals. Modern animal production results in the production of large quantities of manure, which is the source of ammonia. Ammonia endangers the health of farmworkers, animals and the environment itself. In the environment there is a disturbance of the natural balance and the occurrence of acid rain. The influence of animal agriculture on the environment – particularly on climate and ecosystems – is a significant problem in the time of intensification and consolidation of livestock production. Overall production of milk, meat, and eggs has grown fast through the last decades, in particular in developing countries (FAO, 2009). Dairy is a significant part of the livestock sector, producing globally approximately 553 million tonnes of milk in year 2007 (FAOSTAT, 2010) and 34 million tonnes of meat from the dairy-related herd (FAO, 2010). Further, it is quickly increasing: crude milk production raised by 44% between year 1980 and 2007. Furthermore, accordingly to FAO (2006), livestock will remain to be the most dynamic agricultural sub-sector: global production of milk is projected to increase from 580 to 1043 million tonnes in year 2050. This production growth must be accompanied with the appropriate environmental protection measures. In Europe, accordingly to Ruska et al. (2017), the optimum amount of urea in the milk is set at 15–30 mg/dL. In accordance to Hristov et al. (2011) an important part of cattle manure nitrogen, particularly from urinary urea, is transformed into ammonium and finally lost to the atmosphere as ammonia. Various nature of the factors controlling ammonia volatilization, like manure management, ambient temperature, wind speed, and manure composition and pH, complicate defining ammonia emissions from cattle. Reducing ammonia emissions from beef and dairy cattle production is crucial for accomplishing environmentally sustainable animal production that will assist farmers and society at large. Therefore, aim of this paper was to determine the ammonium pollution from dairy cattle in regard to parity and stage of lactation, as well as season using test day records that is applying precision farming methodology.

Material and methods

Test-day records of Holstein cows collected in the period from January 2004 to December 2013 provided by the Croatian Agricultural Agency were used for the statistical analysis. Test-day records were collected during the regular milk recording performed monthly in accordance to the alternative milk recording method (AT4 / BT4) on dairy cattle farms in Croatia. At each recording, measuring and sampling of milk were performed during the evening or morning milkings. Test-day records with lactation stage in (< 5 days and > 500 days), age at first calving in (< 21 and > 36 months), missing parity, missing breed, and missing or nonsense daily milk traits (ICAR standards, 2017) were deleted from the dataset. After logical control dataset consisted of 1,290,058 test-day records from 91,380 Holsteins reared on 6,830 farms.

The milk urea nitrogen (MUN) content was calculated using milk urea content (UREA) accordingly to the following equation:

MUN (mg/dL) = UREA * 0.46 (Spiekers & Obermaier, 2012)

The ammonium emission (AM-EMISS) was calculated using milk urea nitrogen (MUN) accordingly to the following equation:

AM-EMISS (g/cow daily) = 25.0 + 5.03 * MUN (Burgos et al., 2010)

Accordingly, to the parity, cows were divided into four classes: I., II., III., and IV. (animals in fourth and higher lactations). Furthermore, in accordance to the recording date, test day records were divided into four season: spring (March, April, and May), summer (June, July, and August), autumn (September, October, and November), winter (December, January, and February).

Basic statistical parameters of daily milk traits (daily milk yield and contents) as well as milk urea nitrogen and ammonium emission is presented in Table 1.

Table 1. Basic statistical parameters of analysed traits (daily milk traits, milk urea nitrogen (MUN) and ammonium emission)

Variable	N	Mean	SD	CV	Minimum	Maximum
DMY	1290058	21.09	8.83	41.87	3.00	97.60
DFC	1260433	4.17	0.95	22.75	1.50	9.00
DPC	1268661	3.41	0.47	13.82	1.04	6.99
UREA	1190659	22.06	9.89	44.83	0.50	60.00
MUN	1190659	10.15	4.55	44.83	0.23	27.60
AM-EMISS	1190659	76.04	22.88	30.09	26.16	163.83

*DMY – daily milk yield (kg); DFC – daily fat content (%); DPC – daily protein content (%); MUN – milk urea nitrogen (mg/dL); AM-EMISS – ammonium emission (g/cow daily)

For the evaluation of the effect of parity and stage of lactation, as well as season on the variability of daily milk yield; milk urea nitrogen and ammonium emission in Holstein cows following statistical model was used:

$$y_{ijklm} = \mu + b_1(d_i/305) + b_2(d_i/305)^2 + b_3 \ln(305/d_i) + b_4 \ln^2(305/d_i) + S_j + A_k + P_l + e_{ijklm}$$

Where

yijklm = estimated trait; μ = intercept; b1, b2, b3, b4 = regression coefficients; di = days in milk (i = 5 to 500 day); Sj = fixed effect of recording season class j (j = spring, summer, autumn, winter); Ak = fixed effect of age at calving class k (k = 21 to 36 month); Pl = fixed effect of parity l (l = I., II., III., and IV.); eijklm = residual.

The significance of the differences between the parity and season classes was tested by Scheffe's method of multiple comparisons (using the PROC GLM procedure in SAS (SAS Institute Inc., 2000)).

Results and discussion

The analysis of variance of daily milk yield; milk urea nitrogen and ammonium emission showed statistically highly significant effect (p < 0.001) of all effects included in the used statistical model. Lsmeans values of daily milk yield, milk urea nitrogen and ammonium of Holstein cows in accordance to parity classes (I, II, II and IV) are presented in Table 2. All analysed traits differ statistically highly significant (p < 0,001) in regard to parity. Daily milk yield was the lowest in primiparous cows (19.61 kg), while the highest yield was determined in cows in third parity (22.35 kg). Milk produced in second parity had the highest content of milk urea nitrogen as well as ammonium emission was highest in same animals. The lowest amount of milk urea nitrogen as well as lowest emission of ammonium was determined in cows in IV parity.

Table 2. LSmeans of daily milk yield, milk urea nitrogen and ammonium emission regarding the parity for Holstein cows

Parity	DMY	MUN	AM_EMISS
I	19.61^{A}	10.35^{A}	77.06^{A}
II	21.78^{B}	10.43^{B}	77.45^{B}
III	22.35^{C}	10.10^{C}	75.80^{C}
IV	21.71^{B}	9.58^{D}	73.17^{D}

*DMY – daily milk yield (kg); MUN – milk urea nitrogen (mg dL-1); AM_EMISS – ammonium emission (g/cow daily); Lsmeans marked with different letters (A, B, C, D) differ statistically significant (p < 0.001);

The results of analyses of variance of daily milk yield, milk urea nitrogen and ammonium emission of Holstein cows in accordance to season (spring, summer, autumn and winter) are presented in Table 3. Again there were statistically highly significant (p < 0.001) differences for all analysed traits regarding the seasons. The highest recorded daily yield was in spring (22.44 kg); while on the other hand, milk produced in summer had the highest MUN (mg/dL) and ammonium emission (g/cow daily). The lowest daily yield (20.34 kg) was determined in autumn, while the lowest MUN (mg/dL) and ammonium emission per animal was determined in winter.

Table 3. LS means of daily milk yield, milk urea nitrogen and ammonium emission regarding the season for Holstein cows

Season	DMY	MUN	AM-EMISS
Spring	22.44^{A}	9.89^{A}	74.76^{A}
Summer	21.48^{B}	11.91^{B}	84.92^{B}
Autumn	20.34^{C}	9.85^{A}	74.55^{A}
Winter	21.19^{D}	8.80^{C}	69.26^{C}

DMY – daily milk yield (kg); MUN – milk urea nitrogen (mg dL-1); AM-EMISS – ammonium emission (g/cow daily); Lsmeans marked with different letters (A, B, C, D) differ statistically significant (p < 0.001);

Indicator of correct or proper protein and energy balancing in fodder for cows with different productivity characteristics is urea content in milk. According to Ruska et al. (2017), urea content in milk produced in farm where tie stall housing system is, cows are not grouped and are grazed in summer was significant higher. All examined productivity and quality characteristics varied significantly depending on urea content in milk. In case that urea content exceeded 45.0 mg/dL, then milk yield was also significantly higher (25.1 kg). Increased urea content in milk had 33% of examined animals. In accordance to Spohr and Wiesner (1991) and Spann (1993), increased urea in milk reveals a complication related to providing highly productive dairy cows with fodder dosage having sufficient amounts of energy and protein. According to Kohn et al. (2002) and Bucholtz et al. (2007), many studies carried out in Europe have used urea content in milk; on the other side, studies conducting in the USA are usually using different parameter – milk urea nitrogen (MUN) content. MUN is used for efficiency control and desirable MUN content should contain 8.0–12.0 mg/dL. If MUN threshold is exceeded, then farms have to pay attention to the usage of proteins in fodder and their balancing with energy in single feed dose. In accordance to Aguilar et al. (2012), data collected in the USA concerning fodder protein and MUN content show that for reaching MUN limit 12 mg/dL, it is essential to decrease protein amount in food to 12.8% in dry matter. According to Godden et al. (2001) and Haig et al. (2002), for evaluating and planning the farming model is suggested using the urea content parameter from side of scientists from countries assessing nitrogen use and efficiency, with which nitrogen in single feed dose is utilized. For characterizing metabolism processes in the animal body, consequently predicting potential diseases (ketosis, acidosis) on time and managing farming efficiency, it is proved that milk content traits may be used for that and not only for assessing animal productivity. It has been confirmed that there is a meaningful correlation between milk urea content and nitrogen content in animal urine and manure (Burgos et al., 2010; Eckersall & Bell, 2010; Klein et al., 2011; Spek et al., 2013).

Conclusion

The aim of this paper was to determine the variability of daily milk yield, milk urea nitrogen and ammonium emission from dairy cattle in regard to parity (I, II, III, and IV) as well as season (spring, summer, autumn and winter) using precision farming methodology. Statistically highly significant (p < 0,001) effect of on all traits (daily milk yield, milk urea nitrogen and ammonium emission) was determined. Daily milk yield was the lowest in primiparous cows (19.61 kg), while the highest was in cows in third parity (22.35 kg). Milk produced in second parity had the highest content of milk urea nitrogen as well as ammonium emission. The lowest amount of MUN and ammonium emission was determined in cows in fourth parity. When it comes to the season, the highest recorded daily milk yield was in spring; while the milk produced in summer had the highest content of MUN and consequently those cows had the highest ammonium emission. The lowest values of MUN and ammonium emission were recorded in winter.

The results indicate significant variability in ammonium emission due to the characteristics of animal (stage and number of lactation) as well as season effect. Furthermore, test day records could be used not only for assessing animal productivity, also for estimation of ammonium pollution from dairy cattle farms.