FORAGE QUALITY AND DIGESTIBILITY FOR CALCULATION OF ENTERIC METHANE EMISSION FROM CATTLE

Lilija Degola, Aiga Trupa, Elita Aplocina
Latvia University of Agriculture, Institute of Agrobiotechnology
lilija.degola@llu.lv, aiga.trupa@llu.lv, elita.aplocina@llu.lv

Abstract. Forage quality is a significant factor that affects methane (CH_4) production in the cattle intestinal tract. Forage quality, level of concentrate, diet digestibility and feed intake are interrelated and directly affect enteric CH_4 production in the rumen. At the Latvia University of Agriculture Scientific Laboratory of Agronomic Analysis the chemical content of animal feed was analysed; together 93 feed samples from all regions of Latvia. The cattle feed samples were collected from January until December in 2015. The chemical analysis of animal feed was made according to generally accepted zootechnical methods of analysis: dry matter (DM) %, crude protein (CP) %, insoluble protein, %, soluble protein, %, undegraded intake protein (UIP) %, crude fiber (CF) %, acid detergent fiber (ADF) %, neutral detergent fiber (NDF) %, ash %, Ca and P %, according ISO 5983, ISO 6490/2 and ISO 6491 standards, and net energy for lactation (NEL, $MJ \cdot kg^{-1}$ DM) were calculated. Digestibility was determined using the cellulase method. The results show that forages vary significantly in the NDF content and digestibility. Depending on the maturity level of green mass in the harvesting period, the content of NDF in hay was within 51-71 %, in silage 24-48 %, in haylage 38-62 % and in total mixed ration (TMR) 30-45 % of DM. The average digestibility of forage (with the cellulase method): for hay-52.3-53.8 %; for grass silage with preservative 65.2 ± 6.13 %, without preservative 62.8 ± 4.93 %; and for corn silage, respectively 71.1 ± 0.6 %, 68.2 ± 3.1 %; for haylage 62.6 ± 4.08 %, for TMR 71.7 ± 5.68 %. The nutritional value of the analysed forage was good or average. There was no significant difference between the feed digestibility indicators as defined by both the chemical method and the method of calculation. So, there is no need to make the forage digestibility determination in the laboratory with the cellulase method, but the formula (DDM, % = 88.9 – (0.779 x ADF %) can be used, where the digestibility is calculated from the ADF content in feed.

Key words: forage quality, cattle, enteric methane.

Introduction

In the world different databases contain information on enteric methane produced by animals for both – the respiration chamber and SF_6 tracer methods. These data are used to build mathematical models to determine methane formation in the intestinal tract of animals. At present, it is widely used by international groups of scientists, published in the IPCC report 2006, which states "conversion factor" (Ym = % of gross energy (GE), which is converted to methane gas (CH_4)).This factor is used to calculate the "emission factor" (EF = kg $CH_4 \cdot animal^{-1} \cdot year^{-1}$) for each animal species and group.

It is estimated that methane gas emission for animals causes energy loss – an average of 6.5 % of gross energy (GE), which feed gives, is lost in the form of methane gas [1-4]. The forage quality, concentrate level, feed digestibility and feed rations are interrelated factors, and directly affect the intestinal methane - methane (CH_4) production in the rumen. Fodder quality has a significant impact on methane production, and if the quality is poor, the amount of methane gas is growing. The roughage contributes to improving the quality of feed intake and reduces its residence time in the rumen, thereby promoting more efficient energy further digestion processes are used, and in proportion to the reduction of the energy, which is converted to methane gas [5; 6].

The factors, such as plant species, variety and maturity at harvest can affect the roughage quality and digestibility. Concentration of neutral detergent fiber (NDF) and acid detergent fiber (ADF) increases with increasing maturity of the plant and its digestibility decreases. Dietary fibre concentration is one of the factors determining feed intake in ruminants. Feed intake is a critical factor for improving animal productivity, feed efficiency and greenhouse gas (GHG) emissions (both CH_4 and N_2O). Dietary NDF concentration is among the most important regulators of feed intake through the so-called fill limitation mechanism. Thus, the NDF content of the diet and NDF intake are critical for achieving optimum animal productivity and minimizing GHG emissions. An important feed characteristic that can impact enteric CH_4 production is roughage digestibility.

The goal of this research was to estimate the forage quality and digestibility to improve of the calculation of greenhouse gas (GHG) emissions from the cattle intestinal tract.

Materials and methods

The feed samples were collected from conventional cattle farms of different sizes. The choice of the collected amount of feed samples is depending on the number of cattle in the farms (Table 1).

Table1

Feed samples of cattle farms, number

Number of cattle in farm	Feed samples
From 1 till 50	52
From 50 till 200	25
More than 200	16
Total	93

38 farms were surveyed and 93 samples of feed collected, including hay – 24, silage – 47, haylage – 8, total mixed feed (TMR) – 14.

The feed samples were exposed for chemical analyses at the Latvia University of Agriculture Scientific Laboratory of Agronomic Analysis.

The chemical analysis of animal feed was made according to generally accepted zootechnical methods of analysis: dry matter (DM) %, crude protein (CP) %, insoluble protein, %, soluble protein, %, undegraded intake protein (UIP) %, crude fiber (CF) %, acid detergent fiber (ADF) %, neutral detergent fiber (NDF) %, ash %, Ca and P %, according ISO 5983, ISO 6490/2 and ISO 6491 standards, and net energy for lactation (NEL, $MJ \cdot kg^{-1}$ DM) were calculated. Digestibility was determined using the method of cellulase.

Correlation analysis was performed in order to determine the relationship that develops between the digestibility by the cellulase method and the digestibility to the calculation procedure. The calculation method – DDM % = 88.9 – (0.779 x ADF %) [7].

The correlation with digestibility indices and data statistical analysis was determined with MS Excel Data Analysis program package.

Results and discussion

The feed quality in conventional cattle farms is very different. The hay sample (n = 24) test results show that the dry matter content of hay of cereal grasses ranges from 74.5till 96.3 %, cereal grass + legume from 79.9 till 84.2 %, while hay of natural grasslands DM range 81.6-86.4 % (Table 2 and Table 3). Crude protein content in the hay could be evaluated as very low – under 12.0 % (optimum 14-15.0 %) [8]. The hay quality lowering factors were the delayed optimum vegetation stage, which characterized the NDF content. Depending on the mass of green maturity at harvest, the NDF content of the hay ranges from 51.1 % to 65.1 %, while the ADF – from 36.0 to 41.8 % DM. Therefore, the nutritional value expressed by the NEL content also is an average of 5.25-5.74 MJ $NEL \cdot kg^{-1}$ DM (optimally ≥6.0). The hay digestibility is an average of 52.3-61.1 %. The feed value depends on the climate and growing conditions. Plants accumulate calcium better in dry weather, while phosphorus - on the contrary – in wet conditions. The hay samples contain both calcium and phosphorus in a low amount, respectively, an average 0.41-0.78 % and 0.16-0.25 %. In all kinds of hay the content of calcium is predominant to phosphorus. In hay of natural meadows these two mineral ratios are usually 3:1, in hay of clover 5:1, and in hay of alfalfa 7:1. [9].

Chemical analysis averages show that the surveyed farms produce low-quality hay. By studying the correlation between digestibility by the cellulase method and digestibility by the calculation method of the hay, it can be concluded that the linear correlation is an average of strong, a positive functional, characterized by the correlation coefficient r = 0.59.

Good quality silage is important for obtaining high-quality animal products, and in cattle feed rations reduces the need for concentrates. For silage the dry matter content is not desirable lower than 30 %. In our silage samples the dry matter content corresponded to the optimum parameter, cereal grass + legume silage average DM content of 31.6-34.4 % range, while corn silage 30.9-35.6 % (Table 4).

Table2

Average indices of hay in dry matter

Indices	Cereal grasses (n = 12)			Cereal grasses + legumes (n = 5)		
	$x \pm s_x$	Min	Max	$x \pm s_x$	Min	Max
DM, %	86.57 ± 5.05	74.47	96.27	82.33 ± 1.80	79.9	84.23
NEL, MJ·kg^{-1}	5.58 ± 0.23	5.00	5.83	5.74 ± 0.29	5.51	6.05
CP, %	7.39 ± 1.36	5.91	11.02	11.31 ± 3.79	7.6	14.73
Insoluble protein, %	0.60 ± 0.28	0.40	1.06	1.14 ± 0.27	0.88	1.50
Soluble protein, %	2.56 ± 1.40	2.18	4.81	3.29 ± 2.58	2.94	6.21
UIP, % from CP	20.26 ± 11.56	19.1	39.60	24.10 ± 19.28	18.4	44.40
CF, %	32.01 ± 10.68	29.37	41.85	22.19 ± 14.91	28.15	32.24
NDF, %	61.47 ± 3.90	56.27	70.77	51.06 ± 9.18	37.91	59.00
ADF, %	37.83 ± 12.48	34.82	43.16	36.01 ± 3.64	32.09	39.34
Ash, %	5.35 ± 0.99	3.54	6.60	8.50 ± 1.65	6.51	10.40
Ca, %	0.41 ± 0.09	0.27	0.54	0.78 ± 0.28	0.56	1.19
P, %	0.19 ± 0.04	0.12	0.24	0.25 ± 0.05	0.19	0.29
Digestibility with cellulase method, %	53.83 ± 5.19	43.99	60.10	61.10 ± 6.21	54.6	66.90
Digestibility with calculation, %	59.42 ± 3.34	55.27	63.9	60.85 ± 2.83	58.25	63.9

Table 3

Chemical content of natural meadow hay in dry matter (n = 7)

Indices	$x \pm s_x$	Min	Max
DM, %	84.49 ± 5.75	81.56	86.36
NEL, MJ·kg^{-1}	5.25 ± 4.47	4.7	5.94
CP, %	6.11 ± 5.24	5.0	7.98
Insoluble protein, %	0.63 ± 0.33	0.32	1.11
Soluble protein, %	2.39 ± 2.54	1.86	3.40
UIP, % from CP	20.66 ± 18.52	13.48	28.14
CF, %	36.15 ± 43.43	28.15	40.85
NDF, %	65.01 ± 68.58	57.26	70.99
ADF, %	41.80 ± 51.82	33.43	48.76
Ash, %	5.06 ± 5.14	3.96	5.81
Ca, %	0.47 ± 0.42	0.38	0.62
P, %	0.16 ± 0.16	0.12	0.22
Digestibility with cellulase method, %	52.27 ± 4.3	46.95	57.50
Digestibility with calculation, %	56.33 ± 4.82	50.92	62.85

The crude protein content in the cereal grass silage samples is quite low – under 14 % (optimally ≥ 16 %) [8] (Table 4). The corn silage protein content is less than 10 % [1] (Table 5). The grass silage NDF, an average of 43.7-49.2 %, and ADF from 30.4 % to 34.3 % of DM, but in corn silage, respectively, 22.1 % and 22.9 %. The insoluble protein content in both grass silage and corn contained an average of 0.80-0.85 %, and 0.30 to 0.50 % range [8].

Naturally fermented lactic acid content in the samples varies from 2.59 to 4.00 %, 0.21-0.98 % of acetic acid, pH 3.80-5.00, and the feed energy value 4.7-7.0 MJ NEL·kg^{-1} of DM. It is the positive impact on all the silage quality indicators by the grass mass wilting before ensiling.

Silage samples with preservative contain 2.74-3.81 % (mean 3.28 %) lactic acid, 0.56 to 1.18 % (average 0.75 %) acetic acid, pH 3.84-5.24 (mean 4.26), and feed energy value of 5.38 to 7.13 (average 6.18) MJ NEL·kg^{-1} DM. A general activity to prevent butyric acid fermentation is wilting of green mass before ensiling. Of the estimated silage samples in two cases found butyric acid was found. The grass silage digestibility was from 62.8 till 65.2 % (Table 4).

Table 4

Chemical content of silage of cereal grasses + legumes in dry matter (*n* = 38)

Indices	Without preservative (*n* = 29)			With preservative (*n* = 9)		
	$x \pm s_x$	Min	Max	$x \pm s_x$	Min	Max
DM, %	34.36 ± 9.01	17.54	51.07	31.56 ± 7.61	21.77	41.93
NEL, MJ·kg^{-1}	5.64 ± 1.22	4.71	7.00	6.18 ± 11.3	5.38	7.13
CP, %	13.50 ± 3.44	6.3	19.22	13.43 ± 2.54	9.18	17.12
Insoluble protein, %	0.80 ± 0.41	0.21	2.03	0.85 ± 0.4	0.45	1.65
Soluble protein, %	5.50 ± 2.83	2.0	10.97	6.91 ± 1.33	5.08	9.55
UIP, % from CP	31.36 ± 15.32	22.86	49.62	27.99 ± 4.66	22.79	38.11
CF, %	27.24 ± 9.5	16.0	42.17	27.53 ± 3.83	24.07	34.52
NDF, %	49.23 ± 8.15	34.8	61.69	43.66 ± 10.18	24.24	58.38
ADF, %	34.30 ± 5.68	19.7	48.84	30.44 ± 6.57	18.5	40.44
Ash, %	7.80 ± 2.59	3.0	11.03	9.27 ± 1.57	7.4	11.37
Ca, %	0.91 ± 0.41	0.2	1.55	0.89 ± 0.19	0.56	1.11
P, %	0.28 ± 0.05	0.07	0.37	0.28 ± 0.02	0.25	0.32
Acetic acid, %	0.60 ± 0.23	0.21	0.98	0.75 ± 0.19	0.56	1.18
Butyric acid, %	No	No	No	0.1 ± 0.1	0.08	0.20
Lactic acid, %	3.08 ± 0.74	2.59	4.00	3.28 ± 0.43	2.74	3.81
pH	4.40 ± 0.21	3.8	5.00	4.26 ± 0.43	3.84	5.24
Digestibility with cellulase method, %	62.82 ± 4.93	50.85	74.40	65.22 ± 6.13	53.2	71.30
Digestibility with calculation %	62.60 ± 5.82	50.90	74.50	65.17 ± 5.08	57.39	74.33

Table 5

Chemical content of corn silage in dry matter (*n* = 9)

Indices	Without preservative (*n* = 6)			With preservative (*n* = 3)		
	$x \pm s_x$	Min	Max	$x \pm s_x$	Min	Max
DM, %	35.6 ± 6.1	28.8	47.6	30.9 ± 0.2	30.7	31.1
NEL, MJ·kg^{-1}	5.7 ± 2.6	6.6	7.1	6.8 ± 0.1	6.7	6.9
CP, %	8.03 ± 0.58	7.1	8.9	8.3 ± 0.3	8.0	8.5
Insoluble protein, %	0.5 ± 0.1	0.3	0.7	0.3 ± 0.2	0.4	0.4
Soluble protein, %	2.7 ± 2.1	2.1	4.97	1.9 ± 1.7	2.5	3.22
UIP, % from CP	25.0 ± 23.5	23.17	68.5	34.3 ± 30.7	43.9	59.0
CF, %	19.6 ± 2.2	16.0	22.0	14.3 ± 12.4	21.0	22.0
NDF, %	37.9 ± 3.2	33.7	42.7	39.4 ± 2.3	37.0	41.5
ADF, %	22.1 ± 2.0	19.7	25.0	22.9 ± 0.8	22.0	23.70
Ash, %	4.5 ± 2.5	3.0	10.0	3.8 ± 0.2	3.6	4.0
Ca, %	0.2 ± 0.1	0.2	0.3	0.2 ± 0.1	0.2	0.3
P, %	0.2 ± 0.1	0.2	0.2	0.2 ± 0.1	0.2	0.3
Acetic acid, %	0.8 ± 0.1	0.6	0.9	0.6 ± 0.1	0.6	0.8
Butyric acid, %	No	No	No	0.1 ± 0.1	0.1	0.1
Lactic acid, %	3.1 ± 1.1	0.4	3.1	2.6 ± 0.4	2.4	3.0
pH	3.6 ± 0.2	3.3	3.8	3.7 ± 0.1	3.7	3.8
Digestibility with cellulase method, %	68.2 ± 3.1	62.2	71.1	71.1 ± 0.6	70.5	71.7
Digestibility with calculation, %	71.30 ± 1.7	69.4	73.6	71.1 ± 0.66	70.4	71.8

All silage samples showed very low and medium calcium (Ca) content of 0.20-0.91 % on average. Phosphorus content in grass silage evaluated as a low – in average 0.28 %, while in corn silage very low to 0.20 %. The highest digestibility was of corn silage on average from 68.2 % to 71.1 %, while grass silage on average from 62.8 to 65.2 %. By summing all the results it is concluded that silage was of good quality [1; 8]. By studying the correlation between digestibility by the cellulase method and digestibility by the calculation method of grass silage, it can be concluded that the linear relationship is strong, functional positive, characterized by the correlation coefficient $r = 0.77$.

The haylage sample average results show that haylage dry matter content is in the range of 38.5 % to 41.9 % (Table 6). Crude protein of haylage was 8.87 % and 12.35 % in average which is very low. The insoluble protein content is consistent with good and excellent quality (≤ 1.0).The NDF content of haylage varies from 48.67 % to 62.08 % that corresponded to the average quality. The haylage samples showed the presence of butyric acid (0.04 % in average), in some samples till 0.1 % [1; 8].

Table 6

Average indices of haylage in dry matter ($n = 8$)

Indices	Haylage of cereal grasses+legumes ($n = 7$)			Haylage of natural meadow ($n = 1$)
	$x \pm s_x$	Min	Max	
DM, %	41.85 ± 8.7	27.6	49.42	38.52
NEL, MJ·kg $^{-1}$	5.92 ± 0.33	5.52	6.32	5.36
CP, %	12.35 ± 2.59	8.88	15.55	8.87
Insoluble protein, %	0.85 ± 0.21	0.58	1.08	0.52
Soluble protein, %	5.17 ± 4.37	4.14	5.37	4.93
UIP, % from CP	32.54 ± 4.38	25.55	35.72	24.32
CF, %	28.09 ± 5.54	21.81	34.73	37.14
NDF, %	48.67 ± 8.16	38.46	55.70	62.08
ADF, %	33.70 ± 4.33	28.7	38.76	40.70
Ash, %	9.49 ± 3.67	6.76	14.22	7.70
Ca, %	1.04 ± 0.37	0.59	1.46	0.51
P, %	0.22 ± 0.07	0.11	0.30	0.28
Acetic acid, %	0.34 ± 0.2	0.19	0.54	-
Butyric acid, %	0.04 ± 0.06	0.02	0.13	-
Lactic acid, %	2.09 ± 1.22	1.6	3.27	-
pH	4.51 ± 2.31	4.2	6.52	-
Digestibility with cellulase method, %	62.61 ± 4.08	55.8	66.54	56.40
Digestibility with calculation, %	62.64 ± 3.37	58.70	66.54	57.19

It should be considered that in haylage preparation all the requirements are not strictly observed - grass not mowed at the right vegetation stage, there is not effective wilted to 40-50 % dry content and there were other influence factors (rain, prolonged wilting, etc.). The highest digestibility is observed for haylage, which was composed of grasses and legumes – 62.61 %. In general, the quality of haylage can be assessed as medium [1; 8]. By studying the correlation between digestibility by the cellulase method and digestibility of silage by calculation, it can be concluded that the linear relationship is moderately strong, positive functional, characterized by the correlation coefficient $r = 0.93$.

The total mixed ration (TMR) ($n = 14$) analyses showed, that DM was average 42.59 ± 5.86 % of total feed mass, net energy (NEL) 5.78 ± 0.67 MJ·kg^{-1} DM, crude protein 14.88 ± 2.38 % in DM which is an average indicator (high will be 16 % CP in DM), NDF 37.78 ± 12.56 % and ADF 24.73 ± 4.56 % in DM. These indices are very good in total mixed rations, the average DM digestibility is high 71.65 ± 5.68 %.The coefficient of correlation with the digestibility of the calculation method is very close ($r = 0.89$). The digestibility with the calculation method for TMR was 69.71 ± 3.25 % .

Conclusions

1. The average digestibility of forage with the cellulase method: for hay – 52.27 ± 44.3 to 53.83 ± 5.19 %; for grass silage with conservant 65.22 ± 6.13 %, without conservant

62.82 ± 4.93 %; and for corn silage, respectively 71.1 ± 0.6 %, 68.2 ± 3.1 %; for haylage 62.61 ± 4.08 %, for TMR 71.65 ± 5.68 %. These results can be used for calculation of enteric methane emissions from cattle. For ruminants, common ranges of feed digestibility are 45-55 % for crop by-products and range lands, 55-75 % for good pastures, good preserved forages, and grain supplemented forage-based diets, and 75-85 % for grain-based diets fed in feedlots. Our results are similar, middle or little higher, depending on the kind of feed.
2. There was no significant difference between the feed digestibility indicators as defined by both the chemical method and the method of calculation. So, there is no need to make forage digestibility determination in the laboratory with the cellulase method, but the formula (DDM, % = 88.9 – (0.779 x ADF %) can be used, where the digestibility is calculated from the ADF content in feed.

References

1. Lassey K.R. Livestock methane emission and its perspective in the global methane cycle. Australian Journal of Experimental Agriculture, v.48, p.2008, pp. 114-118.
2. Smith, P., Martino, D., Cai, Z., Gwary, D., Janzey, H., Kumar, P. Agriculture. In: Metz, B. (Ed). Climate change 2007: mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2007. 320 p.
3. Johnson K.A., Westberg H.H., Michal J.J., Cossalman M.W. The SF6 tracer technique: methane measurement from ruminants. In: Makkar, H.P.S; Vercoe, P.E. (Ed) Measuring methane production from ruminants. New York: Springer, 2007. chap.3, 36 p.
4. Johnson K.A., Johnson D.E. Methane emissions from cattle. Journal of Animal Science, v.73,1995, pp. 2483-2492.
5. Mathison G.W., Okine E.K., Vaage A.S., Kaske M., Milligan L.P. Current understanding of the contribution of the propulsive activities in the forestomach to the flow of digesta. In: Engelhardt W.V., Leonhard-Marek, S., Breves, G., Giessecke, D. (Ed) Ruminant physiology: digestion, metabolism, growth and reproduction. Stuttgart: Ferdinand Enke, 1995, pp. 23-41.
6. Moss A.R. Methane production by ruminants: literature review of I. Dietary manipulation to reduce methane production and II. Laboratory procedures for estimating methane potential of diets. Nutrition Abstracts and Reviews Series B, v.64, 1994. pp. 785-806.
7. Osītis U., Strikauska S., Grundmane A. Lopbarības analīžu rezultātu apkopojums, LLU, SIA Jelgavas tipogrāfija, 2003. 62. lpp. (In Latvian)
8. Degola L., Trūpa A., Aplociņa E. Lopbarības ķīmiskās analīzes un sagremojamība. ISBN 978-9984-48-219-4, LLU, Jelgava, 2016. 52.lpp. (In Latvian)
9. Latvietis J. Lopbarība. ISBN 978-9984-48-096-1, LLU, Jelgava, 2013, 308 lpp. (In Latvian)