Original Paper

Farm activity input data analysis from suckler cow system

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This paper aims to provide an overview of the suckler beef cow production system in Slovakia and its implications for greenhouse gases (GHG) emissions and ammonia. The study collected data from 24 farms with a total of 3,745 sucker cows in 2021, representing a variety of breeding practices and breeds used for production of weaned calves. The results shown that the farms breeding Charolaise had the lowest proportion (0.61, $n = 8$) of permanent grassland from all land managed in contrast to Pinzgau (0.73, $n = 2$) or Limousine (0.76, $n = 9$) in this database. Preference of winter calving season prevailed representing 38% of all cows (12 farms, 1415 cows) which had achieved calving rate 0.82 ±0.13 of calf per cow and calving interval 420 ±35 days. In the contrast, farms that were not specific about preferred calving season reached rate 0.73 ±0.14 of calf per cow and calving interval 407 ±26 days. Mean average daily gain was 0.978 ±0.23 g.day^{-1} and age at weaning 188 ±48 days. Emission factors were 15.15 ±3.7, 109.7 ±9.3 and 0.800 ±0.07 kg of ammonia, methane and nitrous oxide for cow per year. Present study helps to identify information gaps on various factors such as forage quality, grazing practices, feed rations, and reproductive stage. Data on these variables even from a relatively small number of farms would provide opportunities to overcome the challenges to evaluate on-farm GHG mitigations and their trade-offs.

Keywords: suckler cows, beef, GHG, production efficiency, sustainability indicators

1 Introduction

Extensive livestock farming systems could be seen as viable option for mountain areas to utilize permanent grasslands, support biodiversity in marginal agriculture areas and cultivate landscape (Stolbova & Molcanova, 2009). In suckler beef cow system, cows produce calves fed with its milk until full development of calf's digestive tract. Production system is characterized by low inputs in terms of feed concentrates or fertilizers. Calves are weaned to be used for meat production including fattening of bulls, system with finishing steers or for further breeding to source genetic material (Lancaster & Larson, 2022).

Conversion of roughage to produce beef from suckler cows system has potential to utilize material relatively abundant in extensive grassland areas with low competition for direct food production. On the other hand, this usually low input system is attributed to high methane emissions (CH_4) from enteric fermentation considering amount of CH_4 per unit of product (Richmond et al., 2015). Process of organic matter (OM) fermentation in rumen is expected to yield CH_4 depending on dry matter intake (DMI), but increasing digestibility percentage of OM in the forage reduces CH_4 production per unit of OM fermented in the rumen (Ouatahar et al., 2021). Forage digestibility varies because of intristic changes in cell wall characteristics throughout the stages of ontological development making structural carbohydrates less available for cellulolytic microorganisms in the rumen (Jančík et al., 2010).

Nitrogen in feed undergoes through the losses downstream of each farm component from housing as far as to application. Level of nitrogen in herbage is difficult to influence, especially in production systems relying on grazing mainly extensively managed areas. However, urine and faeces are quickly separated in grassland surface which reduce volatilization of ammonia

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compared to excretions of animals in housing (Rotz, 2018). Emissions of nitrous oxide (N_2O) from handling and storage of excrements are called also "direct" within the scope of Chapter 10 (IPPC, 2019) because part of nitrogen flowing downstream of production process is converted to N_2O during storage of the excrements (EEA, 2019). Nitrogen applied to soil in form of solid manure or slurry is readily available for nitrification and denitrification processes in the soil. The latter mentioned represents contribution to the second largest source of greenhouse gases (GHG) emissions in agriculture which is N_2O from soil (Chadwick et al., 2011).

Number of cows for beef production slightly increased between 2016–2021 representing 37.3% of total number of cows in 2021. The same year calving rate of cows for meat purpose was 0.70 calf per cow (ŠÚ SR, 2021), suggesting that production efficiency remain the main challenge in this sector. Integral assessment of contribution towards sustainable food system in which production parameters as well as environmental indicators meets proper weight is required to scale rational levels of support for breeders (Berton et al., 2017).

The goal of this paper is to summarize actual state of information on suckler beef cow production system in Slovakia in order to describe variability in estimate of GHG emissions and ammonia presented.

2 Material and methods

2.1 Data collection

Data were selected from data sources consisted of the basic natural-economic records of the enterprises (turnover lists of animals, cost calculations, breakdowns of stocks to outputs, etc.) and detailed consultations of the indicators with the management of the monitored farms. The other source was review of published data of country Statistical Office (ŠÚ SR, 2021). Compiled database served to input activity data on animal performance, reproduction, farm practices such as period of calving, age at weaning or use of grazing sections. Farms were selected on purpose to represent variety of farming practices and breeds that occur in suckler beef cow production system in Slovakia. Live weight of cows and calves was not measured rather extrapolated out of available country breeding targets appropriately to the sex and age (ZCHMD, 2023). Calving rate was the number of calves born divided by average number of cows during one year timeframe. We used average values of milk yield 6.0 kilograms (kg) per day (Sapkota et al., 2020) and content of fat 4% and protein 3.5% in milk as the inputs for calculation of energy and protein requirements for milk production. Average daily gain (AVG) of calves was determined based on number of days of age and live weight as the kg of weight gain divided by days at weaning. Breed of livestock was determined as the one prevailing in blood (>75%) of cows in herd. The length of housing of calves was determined from the end of the earliest month in the period until the May when stay of cow – calf pairs on pasture had begun. Therefore, farms with winter calving season were attributed 3 months, spring calving season 1 month and autumn calving season 7 months of housing for calves. Calves accounted in the farms that have not been reported to target specific period of the year were attributed average value (112 days) extrapolated from the durations of other three calving season determined in the way described above.

2.2 Calculations

Guidelines of Intergovernmental Panel on Climate Change (IPCC, 2019) and EMEP/EEA (2019) were used to build sequence and logic of calculations steps for each farm as well as the source of default factors. Percentage of BW to estimate DMI was assigned to each farm based on reproduction stage using formula NASEM (2016):

$$\text{DMI (kg.day}^{-1}) = \left(BW\,(1 - n \text{ of } lactating/cows) \cdot \cdot \text{ DMI \% of BW}\right) + \left(BW\,(1 - n \text{ of } non\text{-}lactating/cows) \cdot \cdot \text{ DMI \% of BW}\right)$$

where: DMI – dry matter intake of cows (kg.day^{-1}); BW – live body weight (kg); DMI % of BW have been attributed as 2.5% for non-lactating and 2.2% of BW for lactating cows. Cows is total number of cows in the survey

Consequently, DMI was multiplied by default factor 18.45 (IPCC, 2019) to calculate GE intake per day and cow. The CH_4 emission factor from enteric fermentation was estimated with the equation (IPCC, 2019):

$$EF = \frac{GE\left(\frac{Y_m}{100}\right) \cdot 365}{55.65}$$

where: EF – CH_4 emission factor of animal per year (kg of CH_4); GE – gross energy intake (MJ.kg^{-1}); Y_m – CH_4 conversion factor estimating percent of GE converted to CH_4 set to 6.5% in this experiment; factor 365 expressed length of the year in days and factor 55.65 (MJ.kg^{-1}) of CH_4 was the energy content of CH_4

In order to calculate EF from MM, volatile solids were defined as the fraction of the diet consumed that is not digested and thus excreted as faecal material, which when combined with urinary excretions, constitutes manure. VS was estimated as (IPCC, 2019):

$$VS = \left[GE\left(1 - \frac{DE}{100}\right) + (UE \cdot GE) \right] \cdot \left[\left(\frac{1 - ASH}{18.45} \right) \right]$$

where: *VS* – the volatile solid excretion per day on a dry OM basis (kg $VS.day^{-1}$); *GE* – the gross energy intake ($MJ.kg^{-1}$); *DE* – the digestibility of the feed OM in percent of feed dry matter; *UE* – the urinary energy, expressed as a fraction of GE, set as $0.04 \times GE$; *ASH* – ash content of feed calculated as a fraction of the dry matter feed intake; factor 18.45 – conversion factor for dietary GE per kg of dry matter ($MJ.kg^{-1}$)

There was no distinction in terms of feed quality among farms, therefore digestibility of feed OM was 55% of dry matter to comply the level of DMI in agreement with guideline of NASEM (2016). Methane conversion factor (MCF) estimate for excrements voided on the pasture was 0.49% and for storage of manure 2.0%. The process of creating Tier 2 emission factors included calculating a weighted average of MCF based on the estimated amount of manure managed by each waste system. This average MCF was then multiplied by the volatile solids (VS) excretion rate and the biomass output for each livestock category (IPCC, 2019).

Dry matter and crude protein (CP) requirements of calves and CP requirements of cows were calculated using equation of Vencl (1991). Nitrogen intake was obtained by dividing CP requirements with 6.25 coefficient. Nitrogen retained was calculated by adapted Equation 10.33 of IPCC (2019) based on milk production of cows or AVG in case of calves. Nitrogen excreted (Nex) was expressed for the animal as the difference in grams (g) of nitrogen per day between nitrogen intake and nitrogen retained using Tier 2 approach of IPCC (2019). At the farm level, ammonia was accounted for by calculating the Nex at housing and pasture, subtracting nitrogen losses at each stage of the production cycle, and converting Nex to ammoniacal nitrogen using default factors of EEA (2019). N_2O was calculated by multiplying Nex with default factors for pasture 0.02 and for housing 0.01 expressed in kg of N_2O Nex-1 (IPCC, 2019). Global Warming Potential for 100-year time horizon (GWP100) was expressed as carbon dioxide equivalent (CO_2 eq) using values of Fifth Assessment Report (Myhre et al., 2013) to multiply emission factor by 28 or 265 for CH_4 or N_2O, respectively.

The descriptive summary statistics were calculated to provide an overview of the data. The mean, standard deviation, minimum, and maximum values were calculated for each variable. Weighted average was used for description of calving rate, calving interval and CO_2 eq per kg of weaned calf live weight.

3 Results and discussion

A total of 3745 suckler beef cows in 24 farms were involved in this study, to summarize information on variability of input data for calculation model of GHG emissions and ammonia at farm level. Data were selected as mean values of performance and reproduction variables for the year 2021. Number of farms, cows and land parameters are shown in the Table 1 grouped by breed. Purebreed animals (single breed prevailing in blood >75%) were involved in majority (22; count) while breeding 5 beef breeds in this database. Farms breeding Limousine represented the highest share of livestock followed by Charloaise and farms with crossbred cows. In terms of land utilization grouped by breed, the largest area of land utilized as grassland belonged to farms breeding Pinzgau and Limousine. Except of breed, live weight of cows varies due to reproduction stage, available pasture and body reserves (D'Occhio et al., 2019). Average values of live weight do not reflect above mentioned aspects and originates from country breeding standards in our model.

Energy and amino acids requirements needed for expenses and losses out of production, remains in relatively steady relationship with live weight compared to potential increase of requirements that occurs with higher production (INRA, 2018). Charolaise is well adapted for breeding conditions in Slovakia reaching growth intensity comparable if not exceeding breeding standard (Darnadiová & Debrecéni, 2009). Proportion of mean grassland area indicates that farms breeding Charolaise which usually matures later reaching higher live weight compared to other breeds in this database could provide more concentrated diets due to higher availability of arable land.

Preferred calving season specified in the Table 2 refers that farmers mostly targeted winter calving season. There were 6 farms breeding the second highest number of cows in aggregate that did not have specific period in which cows gives birth. These farms were connected with the lowest average of calving rate as well. In the opposite, autumn calving season does not enable to use pasture for feeding cows neither calves but it provides opportunity to track ancestors of calves, supply balanced feed ration and housing of animals during winter. Although costs are likely higher compared to other calving seasons, management of such process requires more planning and stress the importance of proper selection of animals for reproduction. Weighted average of calving rate for farms with autumn calving season is the highest but it involves only small fraction of all cows in the database. Average values of calving interval in the Table 2 are

Table 1 Parameters of farms grouped by breed

Breed	Farms	Cows			Land ha			Mean grassland area proportion
		n	ratio	live weight (kg)	mean ±SD	min	max	
Charolaise	8	1,177	0.31	675	1,454 ±1,313	149	3,875	0.61 ±0.2
Limousine	9	1,487	0.40	590	1,191 ±1,287	279	4,330	0.73 ±0.2
Pinzgau	2	197	0.05	500	538 ±189	403	672	0.76 ±0.2
Aberdeen angus	1	49	0.01	580	159 ±0	-	-	-
Simental	2	203	0.05	640	800 ±277	604	996	0.19 ±0.3
Other	2	632	0.17	610	1837 ±1467	800	2874	0.54 ±0.2

farms – number of farms; *n* – number of cows; SD – standard deviation of the mean; ratio – proportion of number of cows (*n*) within a row to total number of cows covered by survey

Table 2 Weighted average for calving rate and calving interval by prefered calving season

Calving season	Farms	Cows (heads)		Calving rate (calf.cow^{-1})			Calving interval (days.cow^{-1})		
		n	ratio	mean ±SD	min	max	mean ±SD	min	max
Winter: December – March	12	1,415	0.38	0.82 ±0.13	0.69	1.06	420 ±35	351	480
Spring: April – June	4	1,099	0.29	0.76 ±0.11	0.71	0.82	401 ±32	367	430
Not specified	6	1,127	0.30	0.73 ±0.14	0.42	0.93	407 ±26	380	436
Autumn: September – November	2	104	0.03	0.93 ±0.19	0.83	1.07	407 ±23	400	415

mean – weightened average for cows included in particular calving season indicated in a row; farms – number of farms; SD – weightened standard deviation; ratio – proportion of calving season in a row to total number of cows

Table 3 Summary statistics of calves performance, age at weaning and lenght of grazing season

Parameter	Animals (heads)	Mean ±SD	Min	Max
Calves ADG at weaning (g.day^{-1})	2,916	0.978 ±0.230	0.441	1.332
Age at weaning (days)		188 ±48	90	271
Grazing season, calves (days)		102 ±67	0	210
Grazing season, cows (days)	3,745	164 ±22	122	185

ADG – average daily live weight gain; farms – number of farms; SD – standard deviation

similar except winter calving season which varied more, considering minimum and maximum values as well.

Range of average daily live weight gain (ADG) of calves in the database was from 0.441 to 1.332 g.day^{-1} shown in the Table 3. Mean live weight at weaning was 220 kg ±65 kg, ranging from 100 kg to 345 kg. Growth rate of breeds with larger body size is larger and require more energy concentrated diets. Calves reach higher growth rate early stage of life when able to intake available milk compared to situations milk production of cows is deficient. In order to produce milk for calve, lactating cow is experiencing periods of negative energy balance covered from body reserves. In the case that quality of feed was limiting factor even for calves reaching higher ADG, cows had to be able to create body reserves before this expense had occurred which could be achieved only by conversion of adequate amount of OM from feed (Galyean & Gunter, 2016). Forage DMI of calves is not neglectable factor, because calves daily weight gain is highly dependent on intake of good quality grass with growing importance throughout grazing season (INRA, 2018).

Average length of grazing season of calves was determined by calving period, age at weaning and date when grazing season had begun or ended. Naturally, cows had longer average grazing season than calves because calves born in spring calving season were not accounted for using whole period of grass growth. There were 4 farms (412 calves; count) that practised weaning in average at 115 days of age, utilization of herbage mass for these calves could be almost exclusively indirect by provision of milk by its cow pair.

As it comes to grazing management, 14 farms used rotational grazing. However, more data on other stocking strategies were not provided, it could be assumed that rotational grazing system could give farmers option to cut forage for ensiling at optimal stage while setting constraints of land availability for grazing to enable higher quality regrowth of grasses. The average number of cows per hectare of permanent grassland was 8.9 ha per one cow. The lower threshold of quartile 2 (25th percentile) was 2.0 and the upper threshold of quartile 3 (75th percentile) was 10.2 hectares of permanent grassland per cow. There is a need to identify optimum biological and economic impacts to continuously asses forage growth, nutrient inputs, pressure on defoliation and animals requirements to match with desired system output (Rouquette, 2015).

Sufficient intake of energy triggers a chain of events that results in the adequate kg of weaned calf per cow. Results of gross energy intake estimation are shown in the Table 4. Coleman et al. (2014) estimated DMI of grazing cows based on live body weight (BW) and OM digestibility which yield remarkably similar patterns with Lalman et al. (2004) practical guidelines on forage intake as the estimated percentage of BW through the range of total digestible nutrients values. Information on BW can provide insights to future reproductive performance of cow as the key indicator for body reserves at critical phases of reproduction. In order to guide nutritional or herd management interventions Body Condition Scoring (BCS) method is preferred in practice (INRA, 2018). BCS is important tool at the farm level, but it is subjective and inconsistent among individual farms or evaluators (Mullins, et al., 2019). For the future developments, it is not feasible to scale up monitoring of BCS for the purpose of more precise DMI estimation in farm-to-farm comparisons, but rather gather information on elements of the product (weaned calf) traceability at the farm level (Smith et al., 2005) such as animal identification and nutritional quality of feeds.

In the Table 5, CO_2 equivalents and GHG emission factors grouped by sources are presented. Predominantly, the largest source of CH_4 is enteric fermentation followed by N_2O from manure management being more than 14 times lower when converted to CO_2 equivalent. In general, major determinants of the amount of CH_4 emissions are DMI and production (Ouatahar et al., 2021). Richmond et al. (2014) estimated by indirect techniques CH_4 emissions and DMI of beef growing cattle grazing two contrasting grassland types in terms of nutritional quality. Group of beef cattle grazing unimproved grassland has been found to have significantly (P <0.001) lower DMI and CH_4 emissions per day. Conversely, poorer nutritive value of unimproved grasslands affecting DMI resulted in significantly (P <0.001) higher CH_4 emissions per unit of BW of growing cattle grazing this area. The quantity of CH_4 per kg of DMI in our research was at the same level (21.6 g) as in the study of Richmond et al. (2014). While the percentage of digestible OM was set to be constant at 55% in our study, the variability in enteric fermentation would likely have increased if data on digestibility were available.

As it comes to carbon footprint, weighted average of kg CO_2 eq per kg of live weight of weaned calf was 19.5 kg which is higher compared to findings of Berton et al. (2017)

Table 4 Mean, standard deviation, minimum and maximum values of intermediate estimates

Parameter	Mean ±SD	min	max
Dry matter intake (kg.dry matter^{-1}.day^{-1})	13.9 ±1.2	11.3	15.4
Gross energy (MJ.day^{-1})	255.8 ±22.0	209.2	284.8
Volatile solids (kg VS.day^{-1})	6.3 ±0.5	5.1	7.0
CP requirements (CP % of DMI)	8,1 ±0.4	7.6	9.1
Nex (nitrogen in g.cow^{-1}.day^{-1})	53.5 ±2.3	48.3	56.0

Nex – nitrogen excreted by cows. CP – crude protein. MJ – megajoules. VS – volatile solids. DMI – calculated dry matter intake. kg – kilograms. g – grams. SD – standard deviation of the mean

Table 5 Descriptive statistics of ammonia and GHG emissions including sources

Parameter	GWP100 (kg.of CO_2 eq.year^{-1})	Emission factor (kg.year^{-1}.cow^{-1})		
		mean ±SD	min	max
Ammonia	–	15.15 ±3.7	4.06	19.46
Greenhouse gases (GHG)				
Methane, total	3,072	109.7 ±9.3	91.0	122.0
Enteric fermentation	3,055	109.1 ±9.3	89.2	121.4
Manure management (MM)	18	0.64 ±0.17	0.45	1.22
Nitrous oxide, direct from MM	212	0.800 ±0.07	0.68	1.05

CO_2 eq – carbon dioxide equivalent of Global Warming Potential – 100 years (GWP100) using values of Fifth Assessment Report (Myhre et al., 2013); MM – manure management who found 15.1 kg of CO_2 eq per kg of body weight sold from French suckler-cow system. This study approached lifecycle of beef, considering factors which would rather increase the estimate, for example carbon footprint of off-farm feed concentrates, veterinary drugs or fuels. On the other hand, higher average body weight of calves, lower level of feed intake as the percentage of body weight were factors that could decrease estimated value of carbon footprint per kg of weaned calf compared to our study.

Overall trend of declining livestock numbers in Slovakia requires less intensive management of permanent grasslands, with regard to changes that occur in herbage yield and floristic composition as the result. Vozár et al. (2022) found increased production capacity in tons per hectare of stands that were moved at least two times a year compared to abandoned and unfertilized spot. At the same experiment, stands at semi natural grasslands increased its proportion of grasses, in two consequent years, while proportions of legumes and other meadow herbs declined (Paulisová et al., 2019). On the other hand, Kizeková et al. (2019) compared stocks of carbon in soil of temporary established grassland at arable land and permanent grassland utilized by grazing of animals throughout one year. Permanent grassland had 56% higher carbon soil stock compared to grassland converted from arable land indicating that production of plant parts that have been decomposed together with animals faeces increased carbon redistribution within soil – plant interactions and contributed to carbon accumulation in soil. Finally, management practices should lead to increased quality of forage that will increase performance and reduce emissions per unit of meat. More data can become available for flexible analysis to select best available scenario through established data sources provided by tools with high frequency of measurements such as near infra-red spectrophotometry or picture analysis. Manure management (MM) involves management and biological processes that takes place from manure generation and treatment until land spreading. Fraction of CH_4 emissions from MM was very low. In this research, CH_4 from MM represented only 0.006% of total CH_4 emissions. There were 14 farms that kept 2295 cows in total (61%) which use solid manure from housing to spread on permanent grasslands. It could be assumed that remaining 39% of solid manure produced by cows throughout the housing season were used for spreading on arable land followed by fast incorporation to soil what reduces volatilization of ammonia. McGinn and Sommer (2007) found that tillage (to 15 cm depth) reduced the of ammonia to air by 76–85% compared to the manure left at the soil surface.

As it comes to emissions from nitrogen cycle at farm level, average Nex per day is presented in the Table 4 and average emission factors for ammonia and N_2O in kg per year are shown in the Table 5. Fraction of ammoniacal nitrogen and N_2O comes from Nex estimated from animal requirements in this model. Emission factors of both gasses have potential to increase with linearly with BW and milk production. In our model, discretion in BW is assumed among breeds. For example, cows in Charolaise farms had Nex 56.0 g per day compared to 48.3 g Nex per day of Pinzgau cows at two farms. There are two sources of variability which were not reflected in actual model. First, for the purpose of this study production of 6.0 kg of milk with 4% fat content per cow day-1 was used, however, milk production varies with breed, maturity, cow parity and lactation stage (Sapkota et al., 2020). Second, grasses of temperate regions are rich in CP content at turn-out of cows during spring months. Progress in stages of vegetation increase fibre content while CP is reduced compared to early stage of vegetation. In this way, grazing cows tends to ingest surplus of CP in spring in combination with low efficiency of nitrogen utilization characteristic for ruminants. In light of the above, Nex emission factor is most likely under-estimated in this study and as the consequence ammonia and N_2O as well.

One of the main benefits of modelling particular animal production systems is the identification of information gaps. Utilization of outcomes of this paper delve in further establishment of means to gather data mainly on forage quality, grazing practices, feed rations or animal identification at specified stage of reproduction. However, relatively small sample of farms could pave the way towards overcoming challenges in harmonizing data structures to reach specific approaches that allow evaluating on-farm GHG mitigating measures to be taken and their trade-offs. In addition, future evaluation of environmental indicators should be seen in accord with overall assessment of agro-ecological system involving grazing livestock in order to design sufficient incentives of famers for sustainable beef production.

4 Conclusions

The enteric fermentation was by far the largest source of CH_4 emissions of cows in farms running cow to calf system in Slovakia. Ammonia emission factors were low but it can be anticipated that larger amount of nitrogen was excreted throughout the season than the quantity calculated from requirements. Factors such as calving rate, calving interval or grassland area varied among farms aggregated by preferred calving season or breed to the large extent. Data on animal identification in link to practices such as grazing management or nutritional value of feeds is needed in robust information systems to manage individual farms as well as whole sector.

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