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The use of mix ration corn-silage based for dairy cattle: A systematic review on methane emission and milk quality

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ABSTRACT. *In subtropical countries, corn silage is the primary ration for dairy cattle. Corn silage is often chosen in mixed rations because of its higher biomass yield, superior palatability, homogeneous yield quality, and simple silage preparation due to its higher soluble sugar content. The review aimed to (i) compile a list of the different feed components that may be combined with corn silage and (ii) compare the results of their effects on methane gas emissions, milk quality, and feed efficiency as determined by an in vivo approach. Relevant papers indexed in the computerized Scopus database and published in a variety of scientific publications were found. This systematic review was based on the PRISMA. Records included in review from databases (n = 10). This method has been applied by the authors in the articles that have been reviewed. In general, the content of CP and EE in the study was almost the same. CH4 (g/d) is lowest at 315-329, and for CH4 (g/kg of DMI) is 15.7-15.9. Substituting ordinary corn silage with Enogen corn silage (ECS) in TMR can increase milk production (38.8-40.8 kg/d) and milk quality (fat 3.82-4%, protein 3.07-3.11% and lactose 4.86-4.92%). The present literature review confirms that all mixed feeds with corn silage base used have nutrient content in accordance with the daily nutrient requirements of dairy cattle. Mixed feed that produces the lowest CH_4 emissions (g/kg of DMI) and good milk quality is by giving ECS (Enogen corn silage).*

Keywords: corn silage, dairy cattle, milk quality, methane emission, total mix ration

INTRODUCTION

Strategic issues that result in fluctuations in the productivity of domestic dairy cattle include the problem of a non-continuous feed supply as a result of seasonal factors. The primary feed for dairy cattle in subtropical countries is corn silage. Choosing the silage process for feed aims to ensure that the feed can be stored and available throughout the year. In the future, silage will not only be an alternative forage storage, but will also become a broader paradigm by improving silage quality through anaerobic bioprocess engineering into complete feeds. The use of Total Mix Ration (TMR) as feed is one of the solutions to meet the nutritional needs of dairy cattle. Corn silage is also often used as a feed ingredients that makes up TMR. Compared to other grasses, corn silage is distinguished by its higher biomass yields, good palatability (Mandi et al., 2018), homogeneous quality at harvest, and ease of silage production due to its higher soluble sugar content (Ali et al., 2019).

Feed for dairy cattle generally has a higher forage ratio than concentrate to increase milk production. However, using the wrong ratio of forage:concentrate will affect the quality of the milk and the resulting methane gas emissions. In particular, ruminants, contribute to the buildup of atmospheric CH_4, and enteric fermentation accounts for 17% of the world's methane sources (Knapp et al., 2014). The higher the methane gas emissions, the more feed energy is not absorbed by the livestock body. Higher DMI is primarily connected to greater milk production (Ferraretto & Shaver, 2015). On the other hand, TMR consists of various types of feed mixed, so the ratio and composition of each component need to be considered. It is hoped that the use of the right mixture can achieve the goals of increasing milk production, milk quality, feed efficiency, and, furthermore, the health of the dairy cattle.

The objectives addressed in the present review and evaluation of the literature from published experiments were (i) to list the various feed ingredients mixed with corn silage, (ii) to compare the result of their impact on methane gas emissions, milk quality, and feed efficiency obtain with in vivo method. Other related parameters such as the type of dairy cattle, experimental period, milk production, and the nutrient content, i.e crude protein and ether extract, were also evaluated in order to comprehensively assess the effect of the mix ration.

MATERIALS AND METHODS

Literature selection and data extraction

A literature search was carried out to identify feed ingredients in the TMR of dairy cattles with corn silage base. Relevant studies published in various scientific journals and indexed in Scopus electronic database were identified, focusing on the relationship between methane emission and milk quality. This systematic literature review was based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) checklist (Liberati et al., 2009). Details for the selection process are provided in Fig 1.

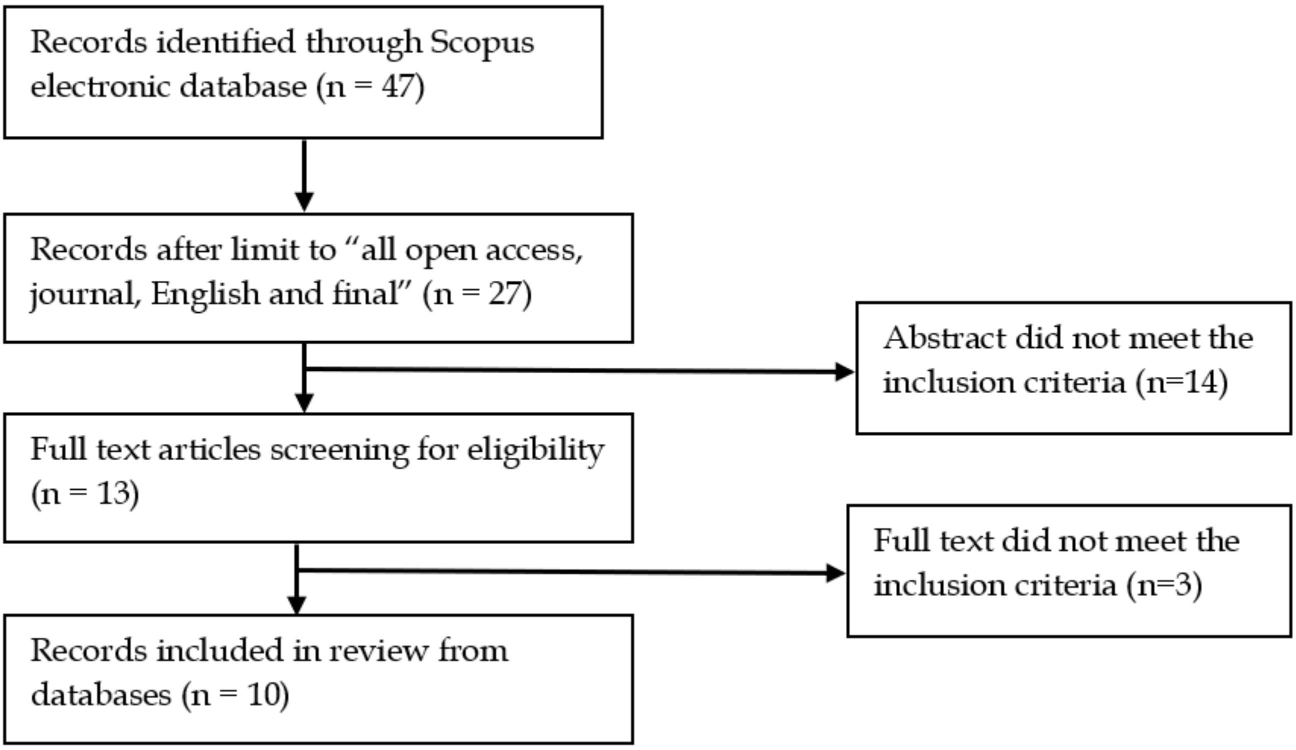

Fig 1. Flow diagram of the search strategy for feed ingredients in TMR with corn silage base

Research articles published were not limited by date, but the articles obtained ranged from 2013 to 2023. Keywords used for finding the relevant articles included "corn silage", "methane", "rumen fermentation", in English. During the selection of literature, titles and abstracts were filtered based on the following criteria, (a) the study used an experimental design and was performed directly on dairy cattle *in vivo* as the experimental animals; (b) the experiment was performed in a controlled-trial environment; and (c) the study provided primary data on feedstuff and its nutrient content, methane gas emissions, and milk quality. After examining the titles and abstracts, we excluded irrelevant studies. Data from each included study was extracted and integrated into the database. The following data were collected: authors, year of publication, feed stuff, animals, experimental period, total sample (n), crude protein (CP), ether extract (EE), neutral detergent fiber (NDF), acid detergent fiber (ADF), methane (CH_4), milk production, milk composition, milk yield, and feed efficiency.

RESULT AND DISCUSSION

Nutrient Content & Methane Emission

Dairy farmers and corn growers strive to produce high-quality corn silage to meet the requirements of high-producing dairy cows. Therefore, developing novel methods and techniques that enhance the nutritive value of corn silage is essential to optimize forage utilization by the cow and achieve greater production efficiencies (Cueva et al., 2021). The use of any feed composition, in giving the total ration, must be adjusted to the needs of dairy cattle. This has been applied by the authors in the articles that have been reviewed. In general, the content of CP and EE in the study was almost the same.

The products of enteric fermentation of fiber i.e methane (CH_4) and carbon dioxide (CO_2), increase as the NDF digestibility value increases. NDF composition in relation to plant maturity (Boadi and Wittenberg, 2002) and plant species (Chaves et al., 2006) has been shown to alter enteric CH_4 emissions under grazing conditions.

Additionally, increasing the amount of concentrate in the diet has been used as a strategy to decrease methanogenesis per unit of feed intake (Doreau et al., 2011). Holstein cattle fed high-concentrate feed, produce low CH_4 emissions with a value of 213 g/d (Olijhoek et al., 2022). Hassanat et al. (2013) reported no change in daily CH_4 emission when replacing alfalfa silage with corn silage; however, dietary EE, which is known to have an inhibitory effect on CH_4 emission (Mores et al., 2013), decreased substantially as the proportion of corn silage increased in the diet

The decrease in CH_4 production was not consistent with the lack of effect on DMI (Tekippe et al., 2011), ruminal fermentation characteristics, *Methanobrevibacter* and protozoa number, the predominant methanogen (Tekippe et al., 2011; Hristov et al., 2013). Several factors can explain this inconsistency, i.e the validity of collecting gas samples and the short duration of CH_4 measurement period (Benchaar, 2020). Moreover, diet supplementation with unsaturated fat is a potentially effective strategy for mitigating enteric CH_4 emissions from ruminants (Beauchemin et al., 2020). On the other hand, one of the major challenges with the use of dietary fats as enteric CH_4 mitigation strategy is to avoid impairing animal productivity (Hassanat and Benchaar 2021). The lowest CH_4 (g/d) value was found in the study conducted (Kolling et al. 2018), and CH_4 (g/kg of DMI) in the study (Cueva et al., 2021).

Table 1. Feedstuff, animal, and nutrient composition

Author	Feedstuff	Animal	Period (d)	n	CP (%)	EE (%)	NDF (%)	ADF (%)
Brask et al., 2013	Barley, Beet pulp dried, Rapeseed meal (4% fat), Rapeseed cake (17% fat), Rapeseed (cracked), Rapeseed oil, Grass silage	Lactating Danish Holstein dairy cows	28	4	16.8-17.1	3.5-6.5	32.2-33.2	-
Arndt et al., 2015	Alfalfa silage, Ground corn grain, Solvent soybean meal, Expeller soybean meal, Soy hulls, Mineral and vitamins	Lactating Holstein cows	21	16	16.6-18	4.3-4.5	27.3-28.1	18.8-21.9
Benchaar et al., 2015	Corn grain (ground), Soybean meal, Rumen bypass protein supplement, Soybean hulls, Linseed oil, Timothy hay, Mineral and vitamin supplement, Urea, Calcium carbonate, Potassium carbonate	Lactating Holstein cows	35	16	16.4-16.6	2.27-5.84	28.2-29.6	17.9-18.5
Guyader, 2017	Hay, Corn, Barley, Soybean meal, Rapeseed meal, Soybean hulls, Wheat bran, Dehydrated beet pulp, Urea, Calcium carbonate, Dicalcium phosphate, Beet molasses,	Lactating Holstein cows (primiparous and multiparous)	35	8	16.1	-	35.1-35.6	18.4-18.7

	Mineral-vitamin mix, Salt, Fungicide, Aroma, Tea saponin extract							
Kolling et al., 2018	Tifton hay, corn, soybean meal, limestone, urea, Ammonium Sulfate, MgO, Sodium bicarbonate, mineral mix	Lactating cows (Holstein and crossbred Holstein-Gir)	44	32	16.8	2.9	43	19.7
Benchaar, 2020	Alfalfa silage, corn grain (rolled), soybean meal (48% solvent-extracted), beet pulp (dehydrated), top supplement, mineral and vitamin supplement, Calcium carbonat	Multiparous cows	28	8	17.9	2.66	31.3	20.8
Gislon et al., 2020	Italian ryegrass hay, corn grain, solvent soybean meal (48% CP), Sugarcane, Mineral and vitamin supplement, rumen-protected methionine	Multiparous lactating Italian Friesian cows	28	8	15	2.34	32.8	22.0
Hassanat and Benchaar, 2021	Soybean meal (48% solvent-extracted), corn grain (ground), soybean hulls, linseed oil, timothy hay (chopped), rumen bypass protein supplement,	Multiparous lactating Holstein cows	35	12	15-16.3	2.67-6.25	32.1-32.9	18.4-19.5

	mineral and vitamin supplement, calcium carbonate, potassium carbonate, urea							
Cueva et al., 2021	Alfalfa haylage, enogen corn silage, straw-hay mix, cottonseed (whole), corn grain (finely ground), canola meal, soyPLUS, molasses, vitamin and mineral premix	Multiparous Holstein cows	42	48	16.5-16.7	3.39-3.63	33.6-33.9	22.6-22.9
Olijhoek et al., 2022	Primary growth grass/clover silage, first regrowth grass/clover silage, barley straw, concentrate mixture, dried beet pulp, barley, wheat, NaOH treated, dried distillers grain, rapeseed cake, soybean meal, molasses (sugarcane), palm fatty acids distillate, vitamin and mineral premix, salt, limestone, Sodium bicarbonate, Magnesium oxide, Titanium dioxide	Dairy cows (Danish Holstein and Danish Jersey)	26	24	15.9-16.4	3.6-3.9	27.8-30.6	-

Note: CP=Crude Protein; EE=Ether Extract; NDF=Neutral Detergent Fiber; ADF=Acid Detergent Fiber

Table 2. Methane emission, milk production, milk composition, milk yield, feed efficiency

Author	CH_4 (g/d)	CH_4 (g/kg of DMI)	Milk Production (kg/d)	Total VFA (m*M*)	Composition (%)			Yield (kg/d)			Feed efficiency (Milk/DMI kg/kg)
					Fat	Protein	Lactose	Fat	Protein	Lactose	
Brask et al., 2013	462-569	25.8-29.6	26.3-31.2	98.6-103	3.79-4.12	3.24-3.35	4.61-4.68	-	-	-	-
Arndt et al., 2015	683-743	25.7-28.1	37.3-38.3	96.8-105.4	3.49-3.67	2.9-3.04	4.89-4.94	1.33-1.40	1.08-1.16	1.83-1.91	1.52-1.60
Benchaar et al., 2015	362-491	16.1-20.1	34.2-35.1	106-120	3.06-3.96	3.26-3.47	4.47-4.62	1.05-1.37	1.10-1.21	1.57-1.60	1.48-1.57
Guyader., 2017	388-395	19.1-22.2	23-28	104.6-110.8	3.13-3.41	3.08-3.15	5.09-5.12	0.80-0.92	0.74-0.92	1.21-1.50	1.31-1.41
Kolling et.al., 2018	315-329	15.3-19.7	26.4-26.8	n.d.	3.9-4.4	3.00-3.25	4.6-4.7	-	-	-	-
Benchaar, 2020	462-511	20.3-21.6	33.6-34.6	140.2-142.4	3.71-3.79	3.27-3.73	4.60-4.62	1.27-1.32	1.08-1.13	1.56-1.61	1.41-1.46
Gislon et al., 2020	378	18.6	27	131	4.38	3.58	5.02	1.16	0.96	1.36	1.33
Hassanat and Benchaar., 2021	346-515	15.7-21.7	31.2-35.1	104-114	3.11-4.04	3.22-3.44	4.48-4.65	1.01-1.25	1.04-1.14	1.41-1.64	1.30-1.53
Cueva et al., 2021	411-420	15.7-15.9	38.8-40.8	86.2-105.1	3.82-4.00	3.07-3.11	4.86-4.92	1.54-1.55	1.20-1.25	1.89-2.00	1.47-1.55
Olijhoek et al., 2022	213-407	15.2-21.0	21.9-36.4	-	3.82-6.51	3.64-4.27	4.69-4.92	-	-	-	-

Milk Production and Milk Quality

Substituting ordinary corn silage with Enogen corn silage (ECS) fermented for approximately 220 d in TMR can increase milk production (38.8-40.8 kg/d) and milk quality (fat 3.82-4%, protein 3.07-3.11% and lactose 4.86-4.92%) (Cueva et al., 2021). Enogen brand corn hybrids (Syngenta Seeds LLC) were originally developed by Syngenta to improve corn ethanol production efficiency. These hybrids are charac terized by the presence of a bacterial transgene express ing high levels of thermotolerant α-amylase (i.e., amy lase-enabled) in the endosperm of the grain. The gene coding for this specific amylase enzyme (AMY797E) is linked to the maize gamma-zein promoter, which causes the protein to be produced and stored primarily in the starchy endosperm of Enogen grain during crop growth, without alteration of the starch or any other nutritional component of the grain (APHIS, 2011). However, in more detail, the fat content of the results of the study (Olijhoek et al., 2022) is higher than (Cueva et al., 2021), the fat value of milk can reach 6.51% produced by Jersey dairy cattle. Differences in breed of dairy cattle can also affect the productivity and quality of milk (Olijhoek et al., 2022). Moreover, Jersey cow had a higher higher apparent total-tract digestibility of crude fat than Holstein (Olijhoek et al., 2018).

Fatty acid components and protein coagulation characteristics in milk can be influenced by the type of silage and the source of starch used as animal feed. Poor milk coagulation will affect the characteristics of the resulting dairy products, one of which is cheese products. The PUFA (polyunsaturated fatty acid) component in milk produced from cows fed corn silage was higher than using sorghum silage. There is a difference in the fatty acid profile between corn silage and sorghum silage, where caprylic, palmitic, butyric and stearic fatty acids in corn silage feed are lower than in sorghum silage, while the lower components are the capric and lauric acid (Cattani et al., 2017).

The quality and composition of milk are affected by the concentration of corn silage added to animal feed, especially its fatty acid components. C10:0 and C12:0 fatty acids increase with the higher concentration of corn silage produced, while total USFA is the opposite (Zaazaa et al., 2022). Yield, total protein, and protein content in the milk produced also showed the same results, where the amount increased as more corn silage was added. This increase is thought to be related to the nutritional balance in the feed given (Waziri and Uliwa, 2020).

The Relationship Between Feed, VFA, Methane and Milk Production

Various dietary approaches have been suggested as potential measures to mitigate methane emissions in dairy cattle (Beauchemin et al., 2009). Obtaining precise measurements of methane output from cattle under different dietary conditions necessitates the utilization of intricate and costly methodologies (Dijkstra et al., 2011). A positive correlation exists between dry matter (DM) consumption and methane gas emissions in cattle. An increase in DM consumption leads to enhanced organic matter (OM) fermentation, resulting in elevated generation of volatile fatty acids (VFA) and fermentation gases (Banninik et al., 2010). Recently, there has been a notable emphasis on developing dependable and cost-effective methodologies for assessing methane emissions from ruminant livestock at an individual-animal level (Souza et al., 2020). The assessment of variability across cows presents an opportunity for the genetic selection of animals with reduced CH4 emissions. This approach is considered an appealing mitigation method due to the cumulative and enduring nature of genetic enhancements (Gransworthy et al., 2012). Milk fatty acids (FA) have shown promise as a methane (CH_4) proxy due to their direct association with microbial digestion in the rumen and energy balance (Negussie et al., 2017).

One potential approach to mitigate feed expenses is incorporating by-products into animal nutrition that possess sufficient nutritional content and exhibit lower economic worth compared to conventional concentrates, such as maize and soybean meal (Ferreira et al., 2017). Many studies have examined lipid supplementation to lower intestinal CH_4 production. In beef and dairy cattle, adding unsaturated fatty acids (UFA) such soy oil (SO) or linseed oil (LO) to the feed reduces gross CH_4 emissions (g/day (d) and per kilogram of output. In addition, UFA supplementation affects the rumen microbial community structure, which seems to last when the supplement is stopped (Lyson et al., 2017). The potential of oregano oil and carvacrol to reduce ruminal methanogenesis in vitro has also been well studied (Benchaar and Greathead, 2011; Cobellis et al., 2016).

CONCLUSION

The present literature review confirms that all mixed feeds with corn silage base used have nutrient content in accordance with the daily nutrient requirements of dairy cattle. Mixed feed that produces the lowest CH_4 emissions (g/kg of DMI) and good milk quality is by giving ECS (Enogen corn silage) fermented for approximately 220 d.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organization related to the material discussed in the manuscript. Conflicts of Interest should be stated in the manuscript.

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