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Review Paper

A brief review of hay or silage use in dairy cow diets and their effect on milk and dairy products

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ABSTRACT

Hay versus silage and their effect on the diet and performance of high-yield dairy cows, as well as on milk production and the quality of cheese has been the subject of research and a brief review of the issue is given here. Hay production and silage are the two most common methods of preserving green mass today and are important nutrients in the diet of cows. However, there has been much controversy about which feed is better and more useful in feeding highly productive cows, hay or silage? Based on studies that have dealt with this issue, information indicates that in recent years in European alpine regions of Switzerland, hay is returning to use in dairy cow diets, not so much because of the yield and quality of milk, but because of the dairy products that are of better quality and tastier if they are made from the milk of hay-fed rather than silage-fed cows. It was also found that the milk of cows with hay in their diet has a higher content of essential fatty acids, which have a beneficial effect on human health.

1. Introduction

Feed has a significant role in animal husbandry and is the main source of carbohydrates, proteins, vitamins and minerals. The choice of feed depends on the nutritional requirements of animals, the availability of land and water resources, and the climatic conditions of a particular area. Cattle feed can be fodder plant-based in the form of hay, silage or fresh green mass, and can be supplemented with other feed sources such as concentrated feeds, minerals and vitamins. Hay and silage are two common methods of preserving fodder plants. Hay is obtained by mowing and drying grasses or legumes, and the quality depends on the type of plant, stage of maturity and environmental conditions. Suitable plants for hay production are with thin stems and more leaves, because they dry quickly and have more protein than cellulose (most types of meadow grasses), and legumes (clover and alfalfa) that are mowed when the flowering phase begins. On the other hand, silage is obtained by fermenting green plants. Fresh green plants are used for silage, primarily cereals (mainly corn and oats) and legumes, which are cut and stored under cover, such as in silos or silo pits. During the storage period, chopped crops in anaerobic conditions undergo a natural fermentation process, which preserves nutrients and extends the shelf life of silage. However, silage has a higher moisture content so it is prone to spoilage if it is not properly preserved and stored. Silage production is the predominant method of preserving fodder crops today,

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as modern silage production technology allows for less dependence on weather conditions. Therefore, silage production has been successively replacing hay production since the 1970s, even on dairy farms in European alpine regions (*Gruber et al*., 2015). However, in the last twenty years, hay feeding has begun to reappear in these regions. The reason for this change is, on the one hand, the successful marketing and promotion of "hay milk", as a specialized product, and on the other hand, technological developments that allow farmers to dry green fodder mass indoors, using energy-efficient and powerful ventilation systems with dehumidifiers.

2. The effect of hay or silage on feed consumption and performance of dairy cows

On examining the effects of hay and silage on feed consumption, different results were obtained. Depending on the study, feed intake was higher when cows were fed hay (*Fasching et al*., 2015), remained unchanged (*Schulze et al*., 2014), or was lower (*Shingfield et al*., 2002) compared to silage. In wetter silages, a lower pH and higher amounts of fermentation end products (lactic acid, short-chain fatty acids, esters, biogenic amines) can reduce feed intake (*Grant & Ferraretto*, 2018). In their study, *Haselmann et al*. (2020) compared the effect of hay and silage from similar home meadows on the diet, feed consumption, and performance of dairy cows. Forage was obtained from meadows dominated by grasses (65% grasses, mainly *Lolium multiflorum* and *L. perenne*; and 35% legumes, mainly *Trifolium pratense* and *T. repens*) and from sowing meadows consisting of 75% grasses (mainly *Dactylis glomerata*, *L. perenne*, *L. multiflorum*, *Trisetum flavescens*, *Alopecurus pratensis*, *Anthoxanthum odoratum*), 20% legumes (mainly *Trifolium repens*, *T. pratense*) and 5% other plants (mainly *Taraxacum officinale* and *Plantago lanceolata*). The results (as indicated in Table 1) showed that cows fed hay rather than silage had greater intake of dry matter (18.3 vs. 17.8 kg/day, respectively) and consumed a higher amount of water-soluble carbohydrates (+1.2 kg/day). Also, hay-fed cows showed a trend towards higher energy excretion via their milk than did silage-fed cows (30.1 and 28.5 kg of energy-corrected milk/day, respectively). The higher content of water-soluble carbohydrates improved the fermentation processes in the rumen, which in turn provided the hay-fed cows with additional amounts of nutrients and energy. In cows that received hay rather than silage, a higher milk fat content was observed (+2.4 g/kg). In terms of milk protein and lactose, no significant differences were observed between the feeding regimes, while the urea content of milk was 1.4 mg/100 mL higher when cows were fed hay. Cows on silage had a significantly thinner consistency of faeces, but the faecal dry matter content did not differ from that of cows fed on hay. The efficiency of feed conversion was almost the same in both groups, while the efficiency of nitrogen conversion was 2% higher in the cows fed with hay. The daily energy yield of milk was 5.26 MJ/NEL higher in the hay group compared to the silage group. The authors concluded that the hay diet improved the efficiency of feed use in dairy cows.

3. The effect of hay or silage in the diet of cows on the quality of milk and cheese

Milk production has always been an important link in the food supply chain. That is why a constant supply of high-quality nutrients is crucial for milk producers. Silage is more flexible and economical compared to hay; however, poorly preserved silage can develop unwanted microorganisms that cause spoilage and a decrease in nutritional value, and even worsen the quality of milk and dairy products, especially mature cheeses. Poor quality silage feeding carries the risk of contamination of raw milk with clostridial endospores, which can cause late-maturation defects in hard and semi-hard cheeses in the later stages of ripening (*Brandle et al*., 2016). *Schaeren et al*. (2005) analyzed milk samples from 18 farms where 12 farms fed silage and six farms operated without silage, finding a higher prevalence of *Clostridium tyrobutyricum* spores in milk

Table 1. Result indicators derived from a study on the effect of hay and silage on dairy cow feed intake and milk components (Haselmann et al., 2020)

	Dry matter intake	E in milk	Milk carbohydrates	Milk urea	Milk lipids	Milk proteins	Milk lactose
Hay	+	+	+	+	+	=	=
Silage	-	-	-	-	-	=	=

from farms where silage was used, with no differences in gross milk composition. Even well-preserved silages can affect the composition and sensory characteristics of cheeses (*Cosentino et al*., 2016). That is why rules were introduced regarding the silage-free diet of dairy cows. The European Union has registered hay milk as a "traditional speciality guaranteed" product, whereby strict criteria regarding milk production must be met (silage must not be used as animal feed) (*European Commission*, 2016; *European Parliament and Council of the European Union*, 2012). This is supported by *Baars et al*. (2012), who found a lower content of phytanic acid in milk from farms that used hay compared to farms that used silage. Moreover, hay milk is described as milk that is suitable for the production of hard cheese. *Van den Oever et al.* (2021) did a significant study that directly provides a comparison of milk from cows fed on hay and milk from cows fed with silage produced from the same plant material. Forage plants from two types of meadows were used, a combination of grass and clover (65% grass, 35% legumes) and a combination of grass, legumes and other herbs (75% grass, 20% legumes, 5% plants). Fodder plants are mowed at the same time and loaded into wagons, either for ensiling in a horizontal silo or fed into a hay crate for drying. The results showed that there are some significant differences between milk from hay-fed cows and milk from silage-fed cows (indicated in Table 2). Linoleic acid, α-linolenic acid, lysine and putrescine showed higher concentrations in the milk of cows fed on hay, while vitamin B2 and spermine were higher in the milk of cows fed on silage. The milk yield of cows averaged 28.8 kg per day. Compared with the hay-fed cow milk, the content of whey protein was higher (+14.3%) in the milk of cows fed with silage, as was the concentration of free amino acids (+20.4%). A slightly higher protein intake in cows fed silage could be partly responsible for the higher concentration of free amino acids in their milk. Compared with the hay-fed cow milk, a higher content of vitamin B2 in the milk of cows fed with silage (+15.8%), as well as vitamin B1 (+3.8%) and vitamin B12 (+12.3%) was found. However, concentrations of vitamins B1 and B12 dropped significantly as the cows produced more milk. Interestingly, in the milk of cows fed on hay, the concentration of vitamins B1 and B12 increased as the milk yield of the cows increased. The vitamin E content was 1.9 times higher in the milk of the cows that received silage than in milk of hay-fed cows. It is assumed that silage offers cows smaller amounts of polyunsaturated fatty acids than does hay, which in turn could increase the concentrations of vitamin E in the milk of cows on silage. The effect of hay or silage on the sensory properties of milk indicates that the attributes (color, consistency and smell) were significantly higher in the milk of cows fed with silage. Other attributes, such as the separation of sour cream, sweetness, or taste, showed almost no differences between the two types of milk.

Manzocchi et al. (2020a) compared the effect of hay and silage obtained from the same plot on the milk and cheese components. The most common plant species on the plot were: 65% grass (*Lolium perenne*, *Phleum pratense*, *Bromus hordeaceus*, *Poa pratense*, *Dactylis glomerata*, *Festuca pratensis*), 15% legumes (*Trifolium repens*) and 20% others (*Taraxacum officinale*, *Veronica chamaedrys*, *Lamium album*). In addition to fodder plants, late-lactating cows received 3 kg/day of dry matter from concentrates. The results showed (Table 3) that the milk of hay-fed cows had a higher protein content and a higher concentration of P (+0.1 g/L) than the milk of silage-fed cows, while the fat and lactose content was similar in both groups. The milk of cows fed on hay had a more intense color compared to the milk of cows fed with silage. A weak yellow tint of milk and cheese was observed in both groups and coincided with the previously observed lower content of carotenoids in the milk of cows fed silage, and especially in milk from cows fed hay. Carotenoids are depleted by photooxidation during wilting and plant preservation, and the carotenoid content of milk is directly related to dietary carotenoid intake (Nozière et al., 2006). The milk of cows fed with silage had

Table 2. Result indicators derived from a study on the impact of hay and silage on milk quality (Van den Oever et al., 2021)

	Linoleic acid	α linoleic acid	Lysine	Putrescine	Vit.B2	Spermine	Whey Proteins	Free amino acids	Vit.E
Hay	+	+	+	+	-	-	-	-	-
Silage	-	-	-	-	+	+	+	+	+

Table 3. Result indicators derived from a study on the impact of hay and silage on milk and cheese quality (*Manzocchi et al*., 2020a)

	Milk proteins	Milk phosphorus	Milk fat	Milk lactose	Milk colour	Sour cream smell	Cheese yield	Cheese pH	Dry matter content of cheese	Salt content of cheese
Hay	+	+	=	=	+	-	+	=	=	=
Silage	-	-	=	=	-	+	-	=	=	=

a stronger smell of sour cream than did the milk of cows fed with hay, which is the result of a higher proportion of PUFAs in the lipids of the silage. The yield of ripe cheese was higher when cows were fed with hay (+128 g/100 kg of milk) rather than silage. The cheeses did not differ in pH, or dry matter, fat or salt contents.

Serrapica et al. (2020) investigated the effect of hay and silage on volatile compounds and sensory properties of hard cheese during ripening. The hard cheese was a traditional semi-hard cheese that is usually produced in the hilly southern part of Italy in small artisanal factories or farms, using milk obtained from animals fed a combination of concentrates, grazing and canned feed. A hybrid of *Sorghum sudanense* × *Sorghum sudanense* (Piper) Stapf. was grown on the plot and after mowing, half of it was ensiled into plastic silo bags, and half was dried to hay. The lactating cows were divided into two groups, one using sorghum hay and the other using sorghum silage. Both groups were given both isonitrogen and isoenergetic mixed feed. Milk from both groups was used to produce three batches of cheese that were 30, 60 and 90 days old. As expected, ensiling increased the solubility of nitrogen so that higher NPN values were observed in the milk of cows fed silage than in milk from hay-fed cows (as indicated in Table 4). There was no difference in milk yield (26.8 vs. 27.0 kg/day) or milk fat (4.07 vs. 4.27). However, milk protein was higher in hay-fed cow milk than in silage-fed cow milk (3.24 versus 3.50). This result, which was also noted by *Verdier-Metz et al.* (2005), may be due to a decrease in rumen microbial protein synthesis in silage-fed cows, which is associated with higher solubility of silage proteins (*Huhtanen et al*., 2003). Consequently, *Vaga and Huhtanen* (2018) observed that dried grass contributes to the provision of ammonia for microbial protein synthesis to a greater extent than silage grass. In cheese made from milk from cows fed with silage, higher amounts of ketones and fatty acids were observed than in the hay-fed counterpart. In contrast, cheese made from milk from hay-fed cows showed the presence of the terpene α-pinene, which was not detected in milk cheese derived from silage-fed cows. The composition of milk, and the chemical and fatty acid composition of the cheese were not significantly different between the feeding regimes. However, cheese ripening provoked changes in sensory characteristics. The silage-based diet induced a greater perceived intensity of color, smell, flavour and texture which allowed the trained panellist to differentiate products and determine the increased consumer preference for "hay" cheese after 30 and 90 days of ripening, thus supporting the marketing strategy for hard cheese to be sold with the Hay milk label.

Manzocchi et al. (2020b) investigated the feeding of dairy cows with hay and different types of silage on feed intake, milk composition, and coagulation properties. They aimed to examine whether the milk of hay-fed cows differs from the milk

Table 4. Result indicators derived from a study on the effect of hay and silage on milk and cheese quality (*Serrapica et al*., 2020)

	NPN	Milk yield	Milk lipids	Milk Proteins	Ketones in cheese	FA in cheese	α-pinene in cheese	Colour of cheese	Smell of cheese	Taste of cheese
Hay	-	=	=	+	-	-	+	-	-	-
Silage	+	=	=	-	+	+	-	+	+	+

Table 5. Result indicators derived from a study on the impact of hay and silage on milk and cheese quality (*Manzocchi et al*., 2020b)

	Milk yield	Milk Lipids	Milk proteins	Lactose	Urea	Acidity of milk	Dry matter intake
Hay	+	+	=	+	-	=	+
Grass silage	-	+	=	-	+	=	+
Corn silage (10mm)	+	+	=	-	=	=	+
Corn silage (30mm)	+	-	=	-	=	=	-

of silage-fed cows and whether the type of silage also has an important influence. Hay, grass silage, conventional short-chopped corn silage and long-chopped corn silage were used in the experiment. All four types of feeds had the same estimated milk production potential and a nutrient-to-concentrate ratio of 0.85:0.15. The first experimental feed was warm-ventilated hay from the first sowing from a permanent meadow dominated by ryegrass. The second forage was silage from ryegrass and clover, harvested during the second and third mowing. The third and fourth feeds were silages from the whole maize plant, both harvested at the stage of milky maturity from the same field and cut to lengths of 10 mm (short-cut) or 30 mm (long-cut) and stored in the same silo container. Absolute milk yield was numerically lower, but not significantly, in cows fed grass silage than cows on the other diets. Among the diets, the milk fat content was the lowest in the milk of cows fed long-chopped corn silage (indicated in Table 5). The milk protein and casein content, as well as the ratio of casein to total milk protein, did not differ between diets. The lactose content was highest in the milk of cows fed with hay compared with the other diets. The urea content was highest in the milk of cows fed grass silage, i.e., urea was twice as high as in the milk of cows fed with hay, and almost the same in the milk of cows fed on corn silage. The acidity of the milk and the parameters of coagulation of rennet did not differ between the diets. The lower dry matter intake from long-shredded corn silage can be explained by the longer retention time of longer particles in the rumen (*Kononoff et al*., 2003), which could slow down rumen emptying and, thus. limit the intake capacity. Despite this lower feed intake, milk yield was not affected by the diet of long-chopped corn silage. However, reduced milk yield was observed with prolonged exposure, as shown by *Mahlkow et al*. (2005) when they fed cows long-shredded corn silage for seven months.

4. The effect of hay or silage in the diet of cows on the concentrations of fatty acids in milk

The composition of fatty acids plays an important role in milk quality and has a long-term impact on human health (*Van Vliet et al*., 2021; *Haug et al*., 2007). Many studies have confirmed the role of fatty acids in the prevention of several chronic human diseases, such as cardiovascular disease, some forms of tumours, obesity and diabetes (*Pereira*, 2014; *Haug et al*., 2007). Increasing the proportion of maize silage in cow diet increased economic efficiency, but reduced the relative contents of fatty acids, such as CLA and n-3 PUFA, in raw milk (*Van Vliet et al*., 2021; *Riuzzi et al*, 2021; *Liu et al*., 2020) and cheese (*Serrapica et al.* 2020). Based on the fatty acid profile, a distinction can be made between grass hay milk and corn silage milk (*Riuzzi et al*., 2021; *Paredes et al*. 2018).

Wang et al. (2023) investigated the effect of hay and silage on the fatty acid status of dairy cow milk. Cows weighing 650 kg producing about 30 kg/day of milk were fed a variety of feeds (dry-based): (1) 46% corn silage as the sole source of feed, (2) a mixture of 23% corn silage and 14% meadow hay (6% alfalfa hay and 8% oat hay) as a feed source, and (3) 28% meadow hay (12% alfalfa hay and 16% oat hay) as the sole source of feed. Hay feeding increased the content of SCFA, CLA, and n-3 PUFA in milk compared to milk from cows fed corn silage (indicated in Table 6). The lower amount SCFAs in the milk of cows fed with maize silage is predominantly due to a decrease in acetate production during rumen fermentation and absorption by the mammary glands. Increasing the proportion of hay in the diet increased intestinal digestion and arteriovenous differences in n-3 PUFAs and total CLA, and, together with higher Δ9-desaturase activity in the mammary glands, resulted in higher relative n-3 PUFAs and total CLA in milk.

Table 6. Result indicators derived from a study on the effect of hay and silage on fatty acid concentrations in milk (*Wang et al*., (2023)

	SCFA	CLA	n-3 PUFA
Hay	+	+	+
Mix	-	-	-
Silage	-	-	-

Schaeren et al. (2005) analyzed the gross milk composition as well as vitamins and minerals in milk from cows fed with or without silage. Although the farms may have had similar production conditions (same region, similar growing conditions, and levels of milk production), the plants came from different plots. There was no significant difference in gross milk composition between the silage-fed and non-silage-fed groups, but the concentrations of conjugated linoleic acid and omega-3 fatty acids were slightly lower in the milk of silage-fed cows. *Paredes et al.* (2018) reported that commercially pasteurized hay milk had a higher content of α-linolenic acid (+37%) and CLA (+22%) than non-hay milk. The study results altogether as summarized in this section show that a higher proportion of hay in the diet of dairy cows increased the relative content of short-chain fatty acids (SCFA), CLA and n-3 PUFA.

5. Discussion

The European Union has registered hay milk as a *traditional speciality guaranteed* product, and therefore, strict criteria must be met regarding production of this milk, i.e., silage must not be used as animal feed (*European Commission*, 2016; *European Parliament and Council of the European Union*, 2012). Studies have confirmed that a hay compared to a silage diet increased feed consumption and energy production in milk in dairy cows (*Haselmann et al*., 2020). Many studies have investigated the effects of feeding dairy cows with hay or silage produced from the same parent plant material, which was important in order to ensure direct comparability, on several components of milk, such as protein fractions, fatty acids, and certain vitamins. The analyzed milk from hay-fed cows and silage-fed cows differed significantly in several components. Higher concentrations of the essential fatty acids, lysine and putrescine, were found in the milk of hay-fed cows, while the milk of silage-fed cows showed higher concentrations of vitamin B12, vitamin E, and spermine (*Van den Oever et al*., 2021). Because of this, as well as intensive marketing campaigns, farmers receive premium prices when hay is the only canned feed used by cows (silage-free meals). Traditionally, in European alpine areas, only milk from hay-fed cows is used to produce semi-hard and hard cheeses from raw milk. In Switzerland, farms that do not use silage account for one-third of total milk production. Cheeses made from raw milk without silage do not show unwanted later swelling during ripening and do not spoil with butyric acid, which has a negative effect on smell and taste (*Wyss & Goy*, 2012). The Swiss government supports the production of milk and cheese without the use of silage in the diet of cows and labels it as hay milk. The products are marketed and sold at a much higher price in several Central European countries (Austria, Germany, Switzerland, France and Italy). In 2016, the term hay milk was included in the European Register of Traditional Specialities Guaranteed and is, thus, protected throughout the EU (*European Commission*, 2016). The product specification hay milk stipulates that the annual diet of dairy herds consists of hay-based feed with at least 750 g/kg dry matter (SM) and that it contains no more than 100 g of concentrate/kg SM (*Verein Heumilch Schweiz*, 2017). In addition to hay and fresh grass, artificially dried grass is also allowed, while the use of all industrial wet feed products is prohibited.

Finally, however, it should be noted that some of the analyzed components in milk from cows fed with silage did not differ significantly from the components in the milk from cows fed with hay. Further research is needed to investigate other effects and possibilities of using silage in the diet of dairy cows.

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