Review article
Pregledni članak

THE EFFECT OF MAIZE SILAGE MATURITY AND CUTTING HEIGHT ON DAIRY COW AND BEEF CATTLE PERFORMANCE

Sara Kolar, Marina Vranić, Lucija Božić, K. Krapinec, Kristina Starčević, T. Mašek, K. Bošnjak

ABSTRACT

Maize silage (MS) is one of the most important energy forage used in ruminant diets because of its high energy content and good palatability. It can be fed as a sole feed or as a component of the ration for dairy and beef cattle. The aim of this paper is to review results published on maize crop maturity and cutting height in relation to yield and quality of MS with respect to dairy and beef cattle performance. As MS cutting height increases, dry matter yield (DM) decreases, but quality (MS) and animal performance increase, which is related to larger proportion of less digestible stalk remaining in the field. Higher cutting height of MS results in lower neutral detergent fibre (NDF) content, higher milk production and consequently lower milk fat (MF) content. MS maturity has a positive effect on animal performance up to a DM content of 280 – 330 g kg^{-1} fresh sample. Thereafter, DM intake, daily milk production (DMP) and crude protein content (CP) in milk mostly decrease or remain the same, as well as daily live weight gain (LWG) of beef cattle due to lower digestibility of organic matter (OM), starch and NDF in MS with higher DM content. It can be concluded that the cutting height and maturity of maize crop represent a kind of a compromise between DM and the starch content in MS, the fibre content necessary to maintain the function and health of the digestive system of ruminants, and the nutrient content of the feed to achieve maximum animal performance.

Key words: maize silage, cutting height, maturity, dairy cows, beef cattle

Introduction

Maize (*Zea mays* L.) is an annual grass of the family *Gramineae*. It can be cultivated under different climatic and pedological conditions (Khan et al., 2014; Santiago Lopez et al., 2017). Along with wheat and rice, it is globally the most represented cereal (Santiago Lopez et al., 2017). The maize plant is very suitable for ensiling, and maize silage (MS) is the most important forage in the diet of dairy and beef cattle due to its high content of energy and dry matter (DM) (Akbar et al., 2002; Allen et al., 2003; Vranić et al., 2004, 2005; Kolar et al., 2022). MS can be fed as a component of the total mixed ration (TMR) or as a sole-feed while maintaining the required amount of crude protein (CP), phosphorus and minerals with the addition of other feed and/or mineral additives (Chamberlain and Wilkinson, 1996).

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Maize crop for ensiling can be harvested at different stages of maturity and at different cutting heights, which affects the ratio of neutral detergent fibre (NDF) to starch in MS (Khan et al., 2012). Harvesting corn too early for ensiling can result in a large loss of nutrients through silage runoff and the production of MS with lower energy content due to low starch concentration in the grain. With the ripening of maize crop for ensiling, daily milk production (DMP) and daily weight gain (DWG) increase up to DM content of 280 – 330 g kg^{-1} fresh sample, after which DM intake, DMP, and CP content in milk decrease (Phipps et al., 2000) as well as the DWG of beef cattle (Keady et al., 2012) due to lower digestibility of organic matter (OM), starch and NDF in MS of higher DM content (> 350 g DM kg^{-1} of the fresh sample) (Khan et al., 2014). Mature MS is lower in nutritive value because of low starch and fiber digestibility (Wiersma et al., 1993; Kolar et al., 2022). The optimal maturity of maize crop for ensiling is at DM content from 350-380 g kg^{-1} of a fresh forage which is 3-4 weeks before the technological maturity of maize grains (Thom et al., 1981), i.e. when the milk line is at half of the grain (Allen et al., 2003).Then, an optimal relationship is achieved between starch, as the energy component of the total mixed ration (TMR), and water-soluble carbohydrates that conserve the whole maize plant by natural fermentation (Vranić et al., 2004) to maximize intake, digestion, and milk production (Bal et al., 1997). MS harvested outside this optimal DM is of greater risk of reduced forage quality and poor preservation (Heather and Lauer, 2002).

Some results suggest that the increasing the height of maize crop cutting, improves the nutritive value of MS for ruminant nutrition because of a larger proportion of less digestible stalk left in the field (Curran and Posch, 2000). The higher content of the NDF reduces *ad libitum* intake of forage which is positively correlated with the digestibility, i.e. the amount of nutrients available to the animal and therefore, to animal performance (Cushnahan and Gordon, 1995; Illius, 1998). Numerous studies have shown that the intake of DM, DMP and the CP in milk (Neylon and Kung, 2003; Bernard et al., 2004; Kung et al., 2008), as well as the DWG of beef cattle (Browne et al., 2004; Mc Geough et al., 2010) increases with increasing harvest height of MS which is positively correlated with forage digestibility (Bernard et al., 2004). Higher DMP may result in higher CP in milk (Seymour et al., 2005; Khan et al., 2012) but in lower MF due to limited production of acetic acid in the rumen when fed higher digestible feed (Abrahamse et al., 2009).

The aim of this paper is to provide a review of results published on maize crop maturity and cutting height on MS yield and quality in terms of dairy and beef cattle performance.

The effect of maize crop maturity and cutting height on maize silage yield and quality

Maize silage (MS) is widely used in the feeding of ruminants due to its high energy value and the high yield of dry matter (DM) ha^{-1}, which most often ranges from 13 - 20 t ha^{-1} (Khan et al., 2014). Higher cutting height of maize crop for ensiling results in lower DM yield per unit area, but higher feeding value (Nylon i Kung, 2003; Lauer, 1998; Kolar et al., 2022). Therefore, the economic aspects of the possible compensation of the lower DM yield at higher cutting MS with higher dairy milk pro-duction (DMP) were considered, some of which are shown in Table 1.

Table 1 The effect of maize silage cutting height on the dry matter (DM) yield and dairy milk production
Tablica 1. Utjecaj visine košnje usjeva kukuruza za siliranje na prinos suhe tvari (ST) i proizvodnju mlijeka muznih krava

MS/KS		Dairy milk production		Reference
CH / VK cm	DM yield / prinos ST	t^{-1} MS intake / t^{-1} konz. KS	ha^{-1}	
15 vs. 46	-15%	+ 3-4%	- 4%	Lauer, 1998
15 vs. 45	- 7.3%	+ 4,9%,	- 1.8%	Wu and Roth, 2005
10.2 to 51	- 12%	+ 7.9%	/	Curran and Posch (2000)
20.4 vs. 50	- 7%	/	/	
12.7 vs. 45.7	- (5-10%)	+ 6% early cut NS late cut	NS	Neylon and Kung (2003)

[1] CH, cutting height; MS, maize silage; DM, dry matter; +, a significant increase in the value of indicators with an increase in cutting height; -, a significant decrease in the value of indicators with an increase in cutting height; NS, non significant effect of cutting height; /, not determined
VK, visina košnje; KS, kukuruzna silaža; ST, suha tvar; +, statistički značajno povećanje vrijednosti s povećanjem visine košnje; -, statistički značajno opadanje vrijednosti s povećanjem visine košnje; NS, statistički beznačajan utjecaj visine košnje; /, nije utvrđeno

It was reported that, with an increase in the cutting height of maize crop, lower DM yield of MS per unit area might be partially offset by higher nutritive value of MS and thus higher animal performance (Bernard et al., 2004; Lewis et al., 2004). Despite, indicators of MS nutritive value show a tendency to increase the performance of animals, they are not always statistically significant because of hybrids (Lewis et al., 2004; Heather and Lauer, 2002) and microclimate environmental factors that may have a significant impact on the quality of MS (Bernard et al., 2004).

The nutritive value of forage in animal feeding is dependent on the concentration of nutrients in DM and the amount of forage an animal can consume. The content of individual parameters of the feeding value of MS reaches its desirable values at different stages of maize plant maturity, i.e. the DM concentration in maize crop. The fiber content in MS is lowest at 350 g DM kg^{-1} of fresh sample, in vitro true digestibility is highest at 300 g DM kg^{-1} fresh sample, and DMP ha^{-1} at 330-370 g DM kg^{-1} fresh sample (Darby and Lauer, 2002).

The DM intake of forage is proportional to the content of DM and inversely proportional to the phase of forage phenological maturity at harvest. The intake of MS increases with advanced maize crop maturity at harvest up to about 350 g DM kg^{-1} fresh sample, after which it decreases due to declining digestibility of starch and neutral detergent fibre (NDF) (Kruczyńska et al. 2011).

Besides maturity, the cutting height also increases DM in MS due to a higher proportion of stover and grain in the forage (Kowalik and Michalski, 2006; Caetano et al., 2011), whereas the cutting height does not affect the DM content of the matured maize crop (< 400 g ST kg^{-1} fresh crops) (Neylon and Kung, 2003). With an increase in the cutting height of maize crop, there is a decrease in the content of NDF in MS and greater digestibility of fiber and DM in the digestive tract of ruminants (Curran i Posch 2000; Kruczyńska et al., 2001; Neylon and Kung, 2003; Kruczyńska et al. 2011). Most changes in MS reported due to increased cutting height have been related to the fact that more fibrous and highly lignified stems are left in the field (Tolera and Sundstøl, 1999).

The effect of maize crop maturity and cutting height on dairy milk production and milk composition

Milk and dairy products are important sources of macro and micronutrients (FAO, 2016). The quantity of produced milk and its's chemical composition is mostly dependent on animal nutrition (Tripathi, 2014) but also on the animal species, individual animal characteristics, number of lactations and lactation stage (Antunac and Samardžija, 2000; Tripathi, 2014; Tyasi et al., 2015).

MS can be fed as a sole feed but more often is fed as a component in TMR. It is an energy component of a daily ration, therefore a good animal performance can be achieved by including protein feed such as grass silage/haylage in a TMR. Grass silage/ haylage are forages rich in CP thus compatible to MS and require supplements rich in fermentable energy such as starch for more efficient nutrient (Ørskov et al., 1970). In addition, MS proteins are relatively non-degradable in the rumen of animals while grass silage/haylage proteins are highly soluble in the rumen. The DM intake of MS is higher compared to grass silage/ haylage because grass silage is higher in NDF content. Therefore, partial replacement of good quality MS with grass silage /haylage increases *ad libitum* intake and *in vivo* digestibility of the TMR (Vranić et al., 2007, Knežević et al., 2007) thus achieving greater animal performance in terms of milk and meat production. The inclusion of grass silage in a ration based on MS of optimal maturity, increases DMP (by 1.9 kg/day) and the content of MF, CP, and lactose in milk (Khan et al., 2014).

The results of previous studies regarding the effect of maize silage from maize crops differing in cutting height and maturity at harvest on dairy milk production (DMP) and milk composition of dairy cows are presented in Table 2.

Table 2 The effect of feeding beef cattle with maize silage differing in cutting height and maturity at harvest on the animal performance (g kg^{-1} DM if not stated otherwise)
Tablica 2. Utjecaj hranidbe junadi u tovu kukuruznom silažom različite visine košnje usjeva kukuruza na proizvodne rezultate (g kg^{-1} ST ako nije drugačije navedeno)

CH/ VK (cm)	MS Maturity Cutting date	Silage DM/ST	% MS in a ration DM	Ration chemical composition			Milk prod. (kg d^{-1})	The milk chemical composition			Reference
				NDF/ NDV	CP/ SP	ME (NEL)		Milk fat	CP/ SP	Lactose	
NS	03.09.	226	75	280	260	13.2	29.4	4.58	3.24	4.76	Phipps et al. (2000)
	19.09.	290					32.7	4.34	3.27	4.76	
	30.09.	302					33.0	4.18	3.19	4.75	
	17.10.	390					30.8	4.46	3.19	4.78	
12.7	1/3 - 2/3 ML	367	40	342	176	/	45.2	3.26	2.84	/	Neylon and Kung (2003)
45.7		387		335	177		46.7	3.03	2.89		
10.2	~ 2/3 ML	358	40.6	416	168	(5.27)	36.7	4.02	3.15	/	Bernard et al. (2004)
		356		395	168	(5.48)	36.6	3.73	3.15		
30.5		352		418	171	(5.36)	37.2	4.06	3.12	/	
		367		404	171	(5.40)	38.2	3.95	3.24		
NS	early	242	~80	413	124	/	14.95	4.11	3.27	/	Fernandez et al. (2004)
	late	318		374	121		15.60	4.20	3.20		
10-15	early dent	337	45	343	175	(6.74)	46.8	3.60	2.88	4.82	Kung et al. (2008)
46-51	early dent	350		341	175	(6.90)	47.7	3.48	2.87	4.83	
NS	14.09.	319	61	374	213	(6.57)	40.2	4.25	3.27	4.66	Khan et al. (2012)
	23.09.	324		364	215	(6.55)	40.8	4.17	3.22	4.62	
	05.10.	361		361	216	(6.52)	40.8	4.21	3.28	4.72	
	14.10.	387		359	215	(6.54)	39.5	4.05	3.29	4.64	
NS	< 250	229	51	NS	NS	NS	25.1	4.07	3.23	/	Khan et al. (2014)
	250 - 300	291					27.7	4.00	3.25		
	300 - 350	331					32.5	3.82	3.33		
	> 350	391					30.4	3.78	3.25		
12	20.09.	283	75	369	145	NS	30.8	4.04	3.08	4.89	Hatew et al. (2016)

CH, cutting height; ML, milk line; DM, dry matter; MS, maize silage; NDF, neutral detergent fibre; CP, crude protein; ME, metabolizable energy; NEL, net energy for lactation; NS, not specified; /, not determined
VK, visina košnje; ML, mliječna linija; ST, suha tvar; NDV, neutralna detergent vlakna; SP, sirovi protein; ME, metabolička energija; NEL, neto energija laktacije; NS, nije navedeno; /, nije utvrđeno

Dairy milk production as influenced by maize silage cutting height and maturity

The basic energy component in dairy cattle ration was MS (Table 2). Its' proportion ranged from 40 to 80% of DM.

The cutting height and crop maturity of MS have a substantial positive effect on net energy for lactation (NEL), but up to a certain maturity of the crop (Neylon and Kung, 2003). With an increase in cutting height of maize crop, the NEL of MS produced from mature maize crop (maize plant of 410 g kg^{-1} fresh crop) is increased, whereas was unaffected in MS of earlier harvest (maize plant of 340 g kg^{-1} fresh crop) (Neylon and Kung, 2003) (Table 2).

Studies revealed that, when feeding dairy cattle with MS originating from maize crops mown to a higher height, DMP increases whereas MF content decreases (Neylon and Kung, 2003; Bernard et al., 2004; Kung et al., 2008). Feeding the dairy cows with MS of a higher cutting height that had NDF digestion improved by 2.5 units may partially explain the tendency for an increase in milk production (+1.5 kg of milk d^{-1}) and improved feed efficiency (Neylon and Kung, 2003).

Milk fat content as influenced by maize silage cutting height and maturity

The most variable ingredient of milk is milk fat (MF). As much as 81 – 83% of the variation in MF quantity is caused by different proportions of structural carbohydrates (NDF and ADF) in TMR of dairy cows. The average content of MF in dairy milk is 3.4 % (Tyasi et al., 2015), while in the presented results (Table 2) it ranged from 3.03% (40% of MS in the ration produced from maize crop cut at 45.7 cm above ground level) (Neylon and Kung, 2003) to 4.58% (75% of MS in a ration produced from a maize crop cut at 12 cm above ground level) (Phipps et al., 2000).

In order to ensure the health of dairy cattle digestion system and an optimal content of MF and CP in milk (Tyasi et al., 2015), a daily ration should contain at least 40 % of forage and 32 – 38% of non - structural carbohydrates (Grbeša and Samardžija, 1994; Tripathi, 2014; Tyasi et al., 2015). Previous studies have demonstrated that lower MS cutting height results in higher fiber content in feed (Neylon and Kung, 2003; Bernard et al., 2004; Kung et al., 2008), and consequently higher MF in milk Tyasi et al., 2015). The effect of NDF in a TMR on MF content in milk of dairy cows is presented in Figure 1.

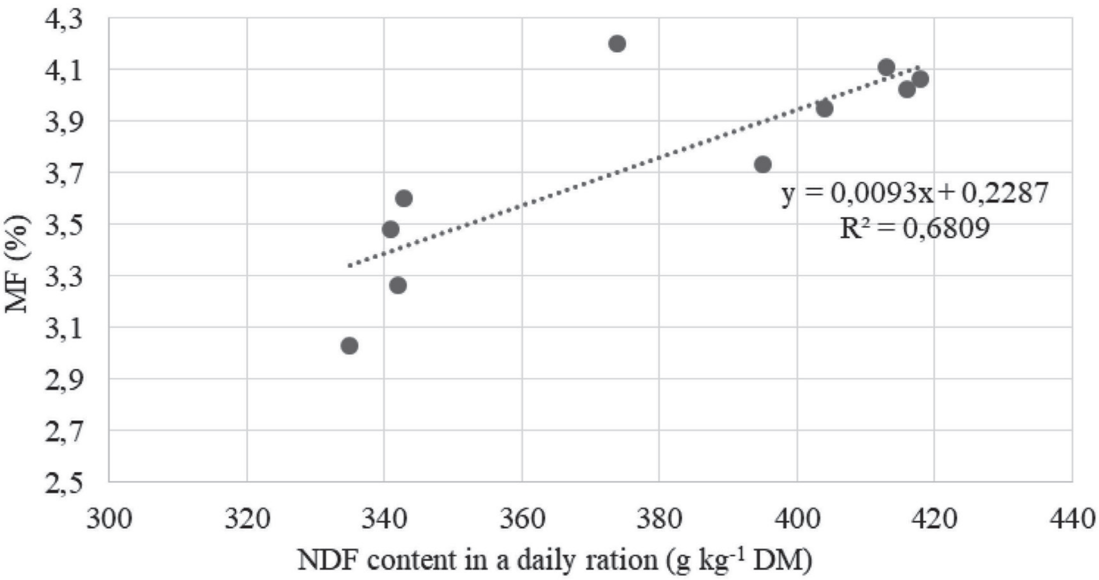

Figure 1 Effect of neutral detergent fiber content (NDF) in a ration on a milk fat content (MF) in the milk. The corresponding equation and determination coefficients (R^2) are indicated in the Figure (Neylon and Kung, 2003; Bernard et al., 2004; Fernandez et al., 2004; Kung et al., 2008)
Grafikon 1. Utjecaj neutralnih detergent vlakana u obroku na sadržaj mlijelčne masti u mlijeku. Pripadajuće jednadžbe i koeficijent determinacije (R^2) su navedeni u grafikonu (Neylon and Kung, 2003.; Bernard et al., 2004.; Fernandez et al., 2004.; Kung et al., 2008.)

MF is positively correlated with forage content in a ration and negatively with CP in milk (Grbeša and Samardžija, 1994; Tripathi, 2014; Tyasi et al., 2015). Thus, the reduction of MF content in milk by 2.8 % increases the CP content by 3.8% (Bernard et al., 2004), whereas reduction of MF content by 5.5 % resulted in an increase of CP content in milk by 0.9% (Phipps et al., 2000). By reducing the proportion of forage in the feed, i.e. fibre content, the production of acetate is reduced, and consequently the content of MF is reduced as well (Figure 1) (Tyasi et al., 2015; Bernard et al., 2004) while production of propionate is increased resulting in higher content of CP in milk (Tyasi et al., 2015).

Lactose in milk as influenced by maize silage cutting height and maturity

It has been observed that feeding has a variable effect on the lactose content in the dairy milk which averages 4.9% (Tyasi et al., 2015), while in the presented results (Table 2) ranged from 4.62% (Khan et al., 2012) to 4.89% in DM (Hatew et al., 2016). The effect of DM content of MS on MF, CP and lactose in milk is presented in Figure 2.

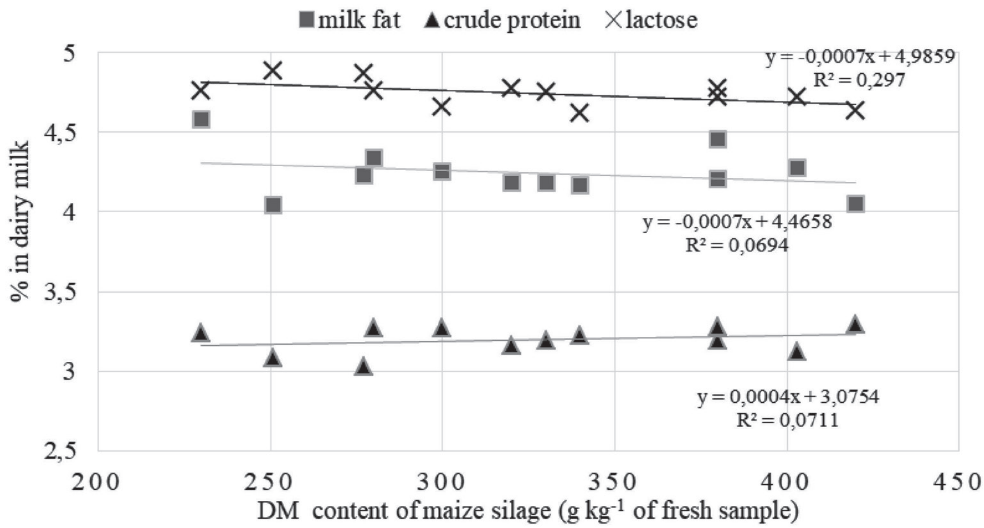

Figure 2 Effect of dry matter (DM) content of maize silage on milk fat, crude protein, and lactose content in dairy milk. The corresponding equations and determination coefficients (R^2) are indicated in the Figure (Phipps et al., 2000; Khan et al., 2012; Hatew et al., 2016).
Grafikon 2. Utjecaj sadržaja suhe tvari (ST) kukuruzne silaže na sadržaj mliječne masti, sirovih proteina i laktoze u mlijeku. Pripadajuće jednadžbe i koeficijent determinacije (R^2) su navedeni u grafikonu (Phipps et al., 2000.; Khan et al., 2012.; Hatew et al., 2016.).

Feeding dairy cattle with MS produced from maize crops harvested at a later stage of maturity resulted in higher DM intake, DMP, and CP content in milk, but lower MF content due to the high starch and lower NDF in MS (Khan et al., 2012) (Figure 2). A slightly negative trend of MS maturity on lactose in milk is observed (Figure 2). As shown in Table 2 with the maturity of the maize crop, DMP increases, whereas MF decreases (Phipps et al., 2000; Khan et al., 2014). The reason is that MS of later stage of maturity is of higher DM intake thus higher milk DMP, and CP content in milk, but lower MF content related to the high starch and low NDF content in DM (Khan et al., 2012). In contrast, with the maturity of maize crops, DMP and MF decreases while CP content in milk increases Khan et al. (2012). Figure 3 presents the effect of DM content in MS on DMP.

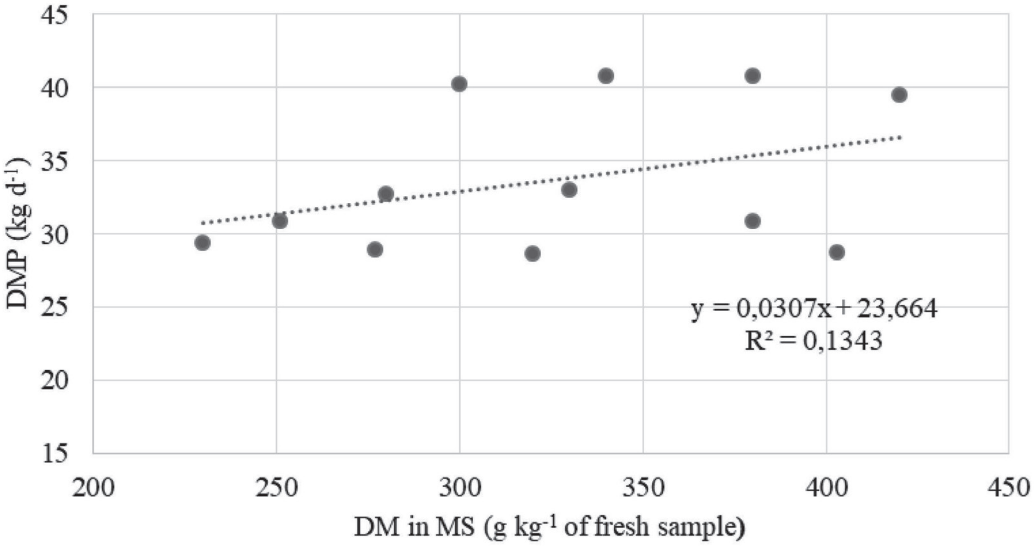

Figure 3 Effect of maize silage (MS) dry matter (DM) on daily milk production (DMP) by dairy cows.The corresponding equations and determination coefficients (R^2) are indicated in the Figure (Phipps et al., 2000; Khan et al., 2012; Hatew et al., 2016).
Grafikon 3. Utjecaj sadržaja suhe tvari (ST) kukuruzne silaže na dnevnu proizvodnju mlijeka muznih krava. Pripadajuće jednadžbe i koeficijent determinacije (R^2) su navedeni u grafikonu (Phipps et al., 2000.; Khan et al., 2012.; Hatew et al., 2016.).

There was a slightly positive trend of MS DM content on DMP presented (Figure 3). It was previously determined that cutting maize crops at DM content of 350 g kg^{-1} fresh crop, compared to cutting at physiological maturity (450 g kg^{-1} fresh crop), does not affect the intake of DM silage, but lowers DMP due to decreased digestibility of OM, ADF and starch (Bal et al., 1997; Harrison et al., 1996). The highest DMP was achieved by including in a TMR the MS of DM content in a range from 280 – 330 g kg^{-1} fresh sample, whereas a significant reduction in the DMP was observed by feeding MS whose DM was close to 380 g kg^{-1} fresh sample (Phipps et al., 2000). The variable effect of MS maturity on DMP can be partly explained by differences in technological ensiling processes, hybrid, genotype, and the effect of DM on fermentation and digestibility of starch (within a range of 92 – 99%) (Hatew et al., 2016).

The effect of maize silage maturity and cutting height on beef cattle performance

Meat and meat products are an important and irreplaceable protein source of animal origin in human nutrition. MS can be used as a sole-feed or as a TMR component in the nutrition of beef cattle.

The results of previous studies about the effect of MS from maize crops differing in cutting height and maturity at harvest on the animal performance of beef cattle are presented in Table 3.

Table 3 The effect of maize silage cutting height and maturity at ensiling on beef cattle performance (g kg^{-1} DM if not stated otherwise)
Tablica 3. Utjecaj visine košnje i zrelosti usjeva kukuruza za siliranje na proizvodne karakteristike junadi u tovu (u g kg^{-1} ST ako nije drugačije navedno)

CH/ VK (cm)	MS maturity/DM/ cutting date Zrelost/DM/ visina košnje	MS DM KS ST	% MS/KS in TMR	Chemical composition of the dietary treatments/ Kemijski sastav obroka			DWG/ prirast (kg d^{-1})	Food conversion ratio/ Konverzija hrane	Reference
				NDF/NDV	CP/SP	ME			
20	NS	357	100	/	/	/	1.200	5.91	Restle et al. (2002)
42		333		/	/	/	1.350	5.58	
12	03.09. early	291	100	NS	130	11.10	1.089	8.71	Browne et al. (2004)
	19.09. medium	339		NS		11.30	1.092	9.99	
	24.09. late	393		NS		11.30	1.094	9.84	
15	NS	290	63	/	/	/	1.450	5.67	Neumann et al. (2007)
39		280		/	/	/	1.540	6.15	
20-25	184	277	100	408	131	11.20	1.208	9.06	Mc Geough et al. (2010)
	222	315		385	127	11.40	1.353	8.85	
	229	339		373	133	11.60	1.246	8.90	
	233	333		370	134	11.30	1.298	8.57	
NS	01.11.	217	50	NS	125	12.70	0.860	8.85	Keady et al. (2012)
			100	NS	130	12.40	0.710	9.88	
	18.10.	304	50	NS	151	13.00	0.880	9.14	
			100	NS	118	11.70	1.030	8.62	
NS	dough	273	50	351	130	11.90	1.700	6.53	Zaralis et al. (2014)
			100	342	141.5	12.20	1.820	6.21	
	dent	376	50	348.5	129.5	11.90	1.640	6.89	
			100	329.5	141.5	12.30	1.740	6.61	

CH, cutting height; DM, dry matter (g kg^{-1} of fresh sample); TMR, total mixed ration; DWG, daily weight gain; MS, maize silage; E, early, M, medium; L, late; NDF, neutral detergent fibre; CP, crude protein; ME, metabolizable energy; NS, not specified; /, not determined.
VK, visina košnje; ST, suha tvar (g kg^{-1} svježeg uzorka); TMR, obrok; KS, kukuruzna silaža; E, rana košnja; M, srednje rana košnja; late, kasna košnja; NDV, neutralna detergent vlakna; SP, sirovi protein; ME, metabolička energija; NS, nije navedeno; /, nije utvrđeno.

Feeding the MS is the most economical decision for beef producers. The proportion of MS in a TMR for beef cattle ranged from 50 to 100% which is more than for dairy cattle (Table 3).

Studies revealed that feeding beef cattle with MS harvested at higher height (20 – 25 cm) resulted in higher daily weight gain (DWG) which ranged from 1208 to 1353 g (Mc Geough et al., 2010), whereas lower cutting height of maize crops (12 cm) resulted in significantly lower DWG (Browne et al., 2004). Those results are in agreement with the results of Bernard et al. (2004) who reported higher animal performance achieved by feeding beef cattle with MS of higher digestibility, thus higher DWG (Browne et al., 2004; Mc Geough et al., 2010).

Feeding beef cattle with MS produced from maize crop cut at a later stage of maturity resulted in higher final body weight and higher DWG (presented in Figure 4) (Keady et al., 2012).

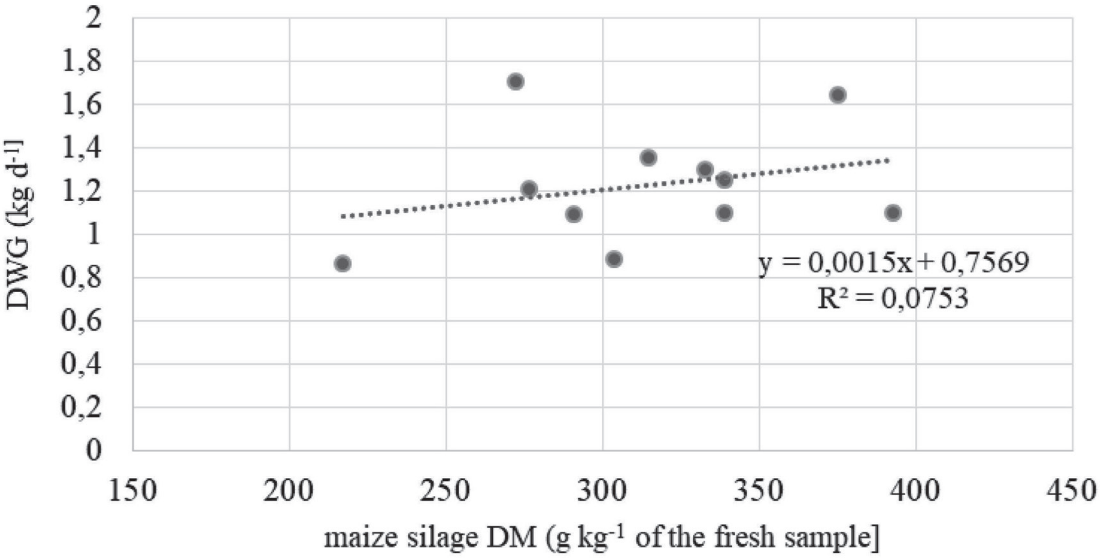

Figure 4 Effect of maize silage dry matter (DM) on daily weight gain (DWG) of beef cattle. The corresponding equation and determination coefficient (R^2) are indicated in the Figure (Phipps et al., 2000; Khan et al., 2012; Hatew et al., 2016).
Grafikon 4. Utjecaj sadržaja suhe tvari (ST) na dnevni prirast junadi u tovu. Pripadajuće jednadžbe i koeficijent determinacije (R2) su navedeni u grafikonu (Phipps et al., 2000.; Khan et al., 2012.; Hatew et al., 2016.).

Similar results were obtained in the study of Zaralis et al. (2014) where a tendency of increased DWG was observed when MS was used as a sole feed, but it was statistically insignificant. Similarly, Mc Geough et al. (2010) and Browne et al. (2004) observed the statistically insignificant effect of maize crop maturity stage on DWG. However, the above-mentioned studies have shown a higher food conversion ratio (FCR) when feeding beef cattle with MS from matured maize crops possibly related to higher starch and lower fiber content in the TMR (Browne et al., 2004).

Conclusion

In conclusion, studies revealed that with an increase in maize silage (MS) cutting height the dry matter (DM) yield decreases but the MS quality increases as well as animal performance which is related to larger proportion of less digestible stalk left in the field. Higher cutting height of MS results in lower neutral detergent fibre (NDF) and consequently lower milk fat (MF).

MS maturity positively affects animal performance up to DM content of 280 – 330 g kg^{-1} fresh sample, after which DM intake, daily milk production (DMP) od dairy cows, and crude protein (CP) in milk mostly decreases or remains the same as well as the daily live weight gain (LWG) of beef cattle due to lower digestibility of organic matter (OM), starch and NDF in MS of higher DM content.

Finally, a cutting height and maturity of maize crop represent a kind of a compromise between DM and starch content in MS, the fibre content necessary to maintain the function and health of ruminant digestive system, and nutrient feed content in order to achieve maximum animal performance.

REFERENCES

1. Abrahamse, P. A., Tamminga, S., Dijkstra, J. (2009): Effect of daily movement of dairy cattle to fresh grass in morning or afternoon on intake, grazing behaviour, rumen fermentation and milk production. Journal of Agricultural Science, 147: 721–730. https://doi.org/10.1017/S0021859609990153.
2. Akbar, M., Lebzien, P., Flachowsky, G. (2002): Measurement of yield and in situ dry matter degradability of maize varieties harvested at two stages of maturity in sheep. Animal Feed Science and Technology, 100(1-2): 53–70. https://doi.org/10.1016/S0377-8401(02)00083-4.
3. Allen, S. M., Coors, G. J., Roth, W.G. (2003): Corn Silage. Silage Science and Technology, 42: 547-608. https://doi.org/10.2134/agronmonogr42.c12.
4. Antunac, N., Samardžija, D. (2000): Proizvodnja, sastav i osobine kozjeg mlijeka. Mljekarstvo, 50(1): 53 – 66.
5. Bal, M. A., Coors, J. G., Shaver, R. D. (1997): Impact of the Maturity of Corn for Use as Silage in the Diets of Dairy Cows on Intake, Digestion, and Milk Production. Journal of Dairy Science, 80(10): 2497 – 2503. https://doi.org/10.3168/jds.S0022-0302(97)76202-7.
6. Bernard, J. K., West, J. W., Trammell, D. S., Cross, G. H. (2004): Influence of corn variety and cutting height on nutritive value of silage fed to lactating dairy cows. Journal of Dairy Science, 87: 2172 – 2176. https://doi.org/10.3168/jds.S0022-0302(04)70037-5.
7. Browne, E., Juniper, D., Bryant, M., Beever, D., Fisher, A. (2004): Intake, live-weight gain and carcass characteristics of beef cattle given diets based on forage maize silage harvested at different stages of maturity. Animal Science, 79 (3), 405-413. https://doi.org/10.1017/S1357729800090275.
8. Caetano, H., Oliveira, M. D. S., Freitas, J. E., Rego, A. C., Renno, F. P., Carvalho, M. V. (2011): Evaluation of corn cultivars harvested at two cutting heights for ensilage. Revista Brasileira de Zootecnia, 40: 12 – 19. DOI: 10.1590/S1516-35982011000100003.
9. Chamberlain, A. T., Wilkinson, J. M. (1996): Feeding the Dairy Cow. Chalcombe Publications, Lincoln, UK.
10. Curran, B., Posch, J. (2000): Agronomic management of silage for yield and quality- Silage cutting height Crop Insights, 10(2): 1-4.
11. Cushnahan, A., Gordon, F. J. (1995): The effects of grass preservation on intake, apparent digestibility and rumen degradation characteristics. Animal Science, 60: 429 - 438. DOI: https://doi.org/10.1017/S1357729800013308.
12. Darby, H., Lauer, J. G. (2002): Harvest Date and Hybrid Influence on Corn Forage Yield, Quality, and Preservation. Agronomy Journal, 94: 559-566. DOI:10.2134/agronj2002.0559.
13. FAO (2016): The Global Dairy Sector- Facts. http://www.dairydeclaration.org/Portals/153/FAO-Global-Facts.pdf?v=1.
14. Fernandez, I., Nozière, P., Michalet-Doreau, B. (2004): Site and extent of starch digestion of whole-plant maize silages differing in maturity stage and chop length, in dairy cows. Livestock Production Science, 89(2-3): 147–157. DOI 10.1016/j.livprodsci.2004.02.011.
15. Grbeša, D., Samaržija, D. (1994): Hranidba i kakvoća mlijeka. Mljekarstvo, 44(2): 119-132.
16. Harrison, J. H., Johnson, L., Riley, R., Xu, S., Loney, K., Hunt, C. W., Sapienza, D. (1996): Effect of harvest maturity of whole plant corn silage on milk production and component yield and passage of corn grain and starch into feces. Journal of Dairy Science, 79: 149.
17. Hatew, B., Bannink, A., van Laar, H., de Jonge, L. H., Dijkstra, J. (2016): Increasing harvest maturity of whole-plant corn silage reduces methane emission of lactating dairy cows. Journal of Dairy Science, 99 (1). 354–368. https://doi.org/10.3168/jds.2015-10047.

18. Heather, M. D., Lauer, J.G. (2002): Harvest Date and Hybrid Influence on Corn Forage Yield, Quality, and Preservation. Agronomy Journal, 94: 559–566. DOI: 10.2134/agronj2002.0559.
19. Illius, A. W. (1998): Advances and retreats in specifying the constraints on intake of grazing ruminants. In: Buchanan-Smith, Proceedings of XVIII International Grassland Congress, Vol III, Association Management Center, Calgary. 39 - 44.
20. Keady, T. W. J., Gordon, A. W., Moss, B. W. (2012): Effects of replacing grass silage with maize silages differing in inclusion level and maturity on the performance, meat quality and concentrate-sparing effect of beef cattle. Animal Science, 7(5): 768 – 777.
21. Khan, N. A., Tewoldebrhan, T. A., Zom, R. L. G., Cone, J. W., Hendriks, W. H. (2012): Effect of corn silage harvest maturity and concentrate type on milk fatty acid composition of dairy cows. Journal of Dairy Science, 95(3): 1472–1483. https://doi.org/10.3168/jds.2011-4701.
22. Khan, N. A., Yu, P., Ali, M., Cone, J. W., Hendriks, W. H. (2014): Nutritive value of maize silage in relation to dairy cow performance and milk quality. Journal of the Science of Food and Agriculture, 95(2): 238–252. DOI: https://doi.org/10.1002/jsfa.6703.
23. Knežević, M., Vranić, M., Bošnjak, K., Grbeša, D., Perčulija, G., Leto, J., Kutnjak, H. (2007): Effects of inclusion of maize silage in a diet based on grass silage on the intake, apparent digestibility and nitrogen retention in wether sheep. Australian Journal of Experimental Agriculture, 47: 1408-1414. doi:10.1071/EA06310.
24. Kolar, S., Vranić, M., Božić, L., Bošnjak, K. (2022): Utjecaj visine košnje i zrelosti usjeva kukuruza za siliranje na kemijski sastav kukuruzne silaže i kvalitetu fermentacije u silosu. Journal of Central European agriculture, 23(2): 290-298. doi:10.5513/JCEA01/23.2.3504.
25. Kowalik, I., Michalski, T. (2006): Influence of selected elements of cultivation technology on the qualitative parameters of maize silage (stay green type variety). Pam. Puł, 142: 201–212.
26. Kruczyńska, H., Darul, K., Nowak, W., Kowalik, I. (2001): The chemical composition and luminal degradability of maize silages depending on the cultivar and mowing height at harvest. Journal of Animal and Feed Sciences, 10: 331-337. DOI:10.22358/jafs/70117/2001.
27. Kruczyńska, H., Darul, K., Nowak, W. (2011): Effect of Mowing Height on Nutritive Value of Maize Silage. Journal of Applied Animal Research, 22(2): 213 – 218. https://doi.org/10.1080/09712119.2002.9706400.
28. Kung, L., Moulder, B. M., Mulrooney, C. M., Teller, R. S., Schmidt, R. J. (2008): The Effect of Silage Cutting Height on the Nutritive Value of a Normal Corn Silage Hybrid Compared with Brown Midrib Corn Silage Fed to Lactating Cows. Journal of Dairy Science, 91(4): 1451–1457. DOI: 10.3168/jds.2007-0236.
29. Lauer, J. (1998): Corn silage cutting height. http://www.uwex.edu/ces/ forage/articles.htm#silage. Accessed December 2021.
30. Lewis, A. L., Cox, W. J., Cherney, J. H. (2004): Hybrid, maturity, and cutting height interactions on corn forage yield and quality. Agronomy Journal, 96: 267 – 274. DOI:10.2134/agronj2004.2670.
31. Mc Geough, E. J., O'Kiely, P., Foley, P. A., Hart, K. J., Boland, T. M., Kenny, D. A. (2010): Methane emissions, feed intake, and performance of finishing beef cattle offered maize silages harvested at 4 different stages of maturity1. Journal of Animal Science, 88(4): 1479–1491. DOI:10.2527/jas.2009-2380.
32. Neumann, M., Muhlbach, P. R. F., Nornberg, J. L., Restle, J., Ost, P. R. (2007): Effect of particle size and cutting height of corn (*Zea mays* I.) during silage processing on young beef cattle production. Revista Brasileira De Zootecnia-Brazilian Journal of Animal Science, 36: 1614 - 1623. DOI:10.1590/S1516-35982007000700021.
33. Neylon, J. M., Kung, L. (2003): Effects of cutting height and maturity on the nutritive value of corn silage for lactating cows. Journal of Dairy Science, 86: 2163–2169. https://doi.org/10.3168/jds.S0022-0302(03)73806-5.

34. Ørskov, E. R.; Fraser, C., Mason, V. C.; Mann, S. O. (1970): The influence of starch digestion in the large intestine of sheep on caecal fermentation, caecal microflora and faecal nitrogen excretion. British Journal of Nutrition, 24: 671-682. DOI: https://doi.org/10.1079/BJN19700068.

35. Phipps, R., Sutton, J., Beever, D., Jones, A. (2000): The effect of crop maturity on the nutritional value of maize silage for lactating dairy cows. 3. Food intake and milk production, 71(2): 401-409. DOI: https://doi.org/10.1017/S1357729800055259.

36. Restle, J., Neumann, M., Brondani, I. L., Pascoal, L.L., da Silva, J. H. S., de Pellegrini, L. G., de Souza, A. N. M. (2002) Corn (*Zea mays*, L.) cutting height during silage processing for young beef cattle production. Revista Brasileira De Zootecnia - Brazilian Journal of Animal Science, 31: 1235 - 1244.

37. Santiago Lopez, U., Rosales-Nieto, C. A., López Santiago, E., Lopez Santiago, N., Preciado-Rangel, P., Gil Palmo, A., Real, D. (2017): Yield of forage, grain and biomass in eight hybrids of maize with different sowing dates and environmental conditions. Revista Mexicana de Ciencias Pecuarias, 9: 86. https://doi.org/10.22319/rmcp.v9i1.4403.

38. Seymour, W. M., Campbell, D.R., Johnson, Z.B. (2005): Relationships between rumen volatile fatty acid concentrations and milk production in dairy cows: A literature study. Animal Feed Science and Technology, 119: 155–169. DOI:10.1016/j.anifeedsci.2004.10.001.

39. Thom, E. R., Dorofaeff, F. D., Dyson, C. B. (1981): Effect of Plant-Population and Time of Harvest on Yield and Quality of Maize (Zea-Mays-L) Grown for Silage. Yield and Chemical-Composition, and Sampling Procedures for Large Areas. New Zealand Journal of Agricultural Research, 24: 285 - 292. https://doi.org/10.1080/00288233.1981.10423389.

40. Tolera, A., Sundstøl, F. (1999): Morphological fractions of maize stover harvested at different stages of grain maturity and nutritive value of different fractions of the stover. Animal Feed Science and Technology, 81: 1-16. DOI:10.1016/S0377-8401(99)00072-3.

41. Tripathi, M. K. (2014): Effect of Nutrition on Production, Composition, Fatty acids and Nutraceutical Properties of Milk. Journal of Advances in Dairy Research, 2(2): 115. DOI: 10.4172/2329-888X.1000115.

42. Tyasi, T., Gxasheka, M., Tlabela, C. (2015): Assessing the effect of nutrition on milk composition of dairy cows: A review. International Journal of Current Science, 17: 56-63. ISSN 2250-1770.

43. Vranić, M., Knežević, M., Perčulija, G., Grbeša, D., Leto, J., Bošnjak, K., Rupić, I. (2004): Kvaliteta kukuruzne silaže na obiteljskim poljoprivrednim gospodarstvima. Mljekarstvo, 54(3): 175-186. https://hrcak.srce.hr/1558.

44. Vranić, M., Knežević, M., Leto, J., Perčulija, G., Bošnjak, K., Kutnjak, H., Maslov, L. (2005): Kvaliteta voluminozne krme na obiteljskim poljoprivrednim gospodarstvima u Republici Hrvatskoj: Monitoring kvalitete kukuruzne silaže tijekom dvije sezone zimske hranidbe muznih krava. Mljekarstvo, 55(4): 269 – 282. https://hrcak.srce.hr/492.

45. Vranić, M., Knežević, M., Bošnjak, K., Leto, J., Perčulija, G. (2007): Feeding value of low-quality grass silage supplemented with maize silage for sheep. Agricultural and Food Science, 16: 17-24.

46. Wiersma, D. W., Carter, P. R., Albrecht, K. A., Coors J. G. (1993): Kernel milkline stage and corn forage yield, quality, and dry matter content. Journal of Production in Agriculture, 6: 94–99. https://doi.org/10.2134/jpa1993.0094.

47. Wu, Z., Roth, G. (2003): Considerations in managing cutting height of corn silage. Extension publication DAS 03-72. Pennsylvania State University, College Park.

48. Zaralis, K., Nørgaard, P., Helander, C., Murphy, M., Weisbjerg, M. R., Nadeau, E. (2014): Effects of maize maturity at harvest and dietary proportion of maize silage on intake and performance of growing/finishing bulls. Livestock Science, 168: 89–93. https://doi.org/10.1016/j.livsci.2014.07.013.

UTJECAJ ZRELOSTI I VISINE KOŠNJE USJEVA KUKURUZA ZA SILIRANJE NA PROIZVODNE KARAKTERISTIKE MLIJEČNIH KRAVA I JUNADI U TOVU

Sažetak

Kukuruzna silaža (KS) je jedno od glavnih energetskih krmiva koja se koriste u hranidbi preživača zbog visokog sadržaja energije i visoke palatabilnosti. Može se koristiti kao jedino krmivo ili kao komponenta obroka za mliječna i tovna goveda. Cilj ovog rada je dati pregled objavljenih rezultata istraživanja zrelosti usjeva kukuruza za siliranje i visine košnje na proizvodnost mliječnih i tovnih goveda. S povećanjem visine košnje usjeva kukuruza za siliranje smanjuje se prinos suhe tvari (ST) KS, povećava se kvaliteta KS kao i proizvodnost životinja uglavnom radi veće kvalitete KS. Veća visina košnje KS rezultira nižim sadržajem neutralnih detergent vlakana (NDV), većom proizvodnjom mlijeka i posljedično nižim sadržajem mliječne masti (MM) u mlijeku. Zrelost KS pozitivno utječe na proizvodnost životinja do sadržaja ST od 280 – 330 g kg-1 svježeg uzorka, nakon čega se dnevna konzumacija (ST), proizvodnja mlijeka i sadržaj SP u mlijeku uglavnom smanjuje ili ostaje isti kao i dnevni prirast goveda radi niže probavljivosti organske tvari (OT), škroba i NDV u KS većeg sadržaja ST. Može se zaključiti da visina košnje i zrelost usjeva kukuruza za siliranje predstavljaju svojevrsni kompromis između sadržaja ST i škroba u KS, sadržaja vlakana potrebnih za održavanje funkcije i zdravlja probavnog sustava preživača, te sadržaja hranjivih tvari u obroku za postizanje maksimalne proizvodnosti životinja.

Ključne riječi: kukuruzna silaža, visina košnje, zrelost, muzne krave, tovna goveda

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