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CUT LENGTH DISTRIBUTIONS OF HAYLAGE PARTICLES

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Abstract

Alfalfa is one of the most important crops for forage production. Traditional method of alfalfa conservation assumes hay preparation. However, nowadays it is also commonly processed in the form of silage and haylage. Physiological effects of forages that are included in diets depend on plant species, stage of maturity, method of preservation and diet composition. Physical characteristics of rations for ruminants are primarily influenced by dietary forage to concentrate ratio, type of forages and concentrates, and mean particle size of feeds. Length distribution of forage particles represents an important parameter for ruminant's diet formulation, especially for dairy cattle. During silage production, harvest considerations should be focused to obtaining the adequate particle size distribution of the ensiling crop particles.

This paper presents results of testing three contemporary types of self-propelled silage harvesters applied in the alfalfa haylage preparation: Claas Jaguar 950, Krone Big X 700 and Krone Big X 500. All machines were adapted with pick-up headers. In the study are analyzed length distributions of chopped alfalfa particles. Resulting frequency distributions of produced haylage are characterised by high mass percentage of the fraction comprehending the largest particles. It is also evident that harvester Class Jaguar 950 achieved the mean chopping length closest to preset value.

Key words: *alfalfa, chopper, cutterhead, length fraction, silage harvester*

Introduction

Alfalfa (*Medicago sativa* L.) plant, also called lucerne, is a relevant source for dairy cows feeding. Thanks to extensive adaptability and high nutritive value, alfalfa is the most widely cultivated forage legume worldwide. This crop is characterised by high level of proteins, vitamins and minerals content, but it does not contain the minimum sugar percentage needed for successful fermentation. However, producing the haylage by ensiling, compared to hay, is less sensitive toward the weather conditions, what results in smaller looses.

Haylage is preserved fodder of green plants that arise as a combination of wilting and ensiling. Under typical climate conditions in Serbia followed by dry farming, first moving of alfalfa crop provides the highest yield. Unfortunately, this period of the year is characterised by frequent rains, atmospheric and soil humidity. Consequently, harvested mass of wet alfalfa raw material is difficult to dry and leaves quickly fall, causing the loss of quality. In order to control the nutrient degradation during legumes ensiling, different methods can be used: wilting, carbohydrate stimulation, inoculation and chemical preservation (Nadeau et al., 2000).

In opposite, haylage quality and production process are less dependent on weather conditions, than hay preparation, because hay production demands longer period for crops wilting in the field. During the haylage production process, alfalfa is left on the land for only few hours or maximum the whole day (depending on the temperature) in order to reduce the moisture to about 50 %. Finally, wilted alfalfa mass is collected, chopped and transported to the silo (Horrocks and Valentine, 1999).

In Serbia, alfalfa is the most important perennial forage crops, and is the second most important forage crop after maize. It is grown on 178,000 ha (STAT.YEARB.SERB. 2013). Contemporary agricultural production of alfalfa assumes machine crop harvesting. Modern self-propelled precision-cut forage harvesters, when combined with large transport units, reach a high harvest performance, over 150 tons of fresh material per hour (Shinners, 2003). However, besides harvesters of modern design (Marković et al., 2006; Potkonjak et al., 2010), the interest for non-contemporary models still exists in transition countries like Serbia (Stanimirović et al., 2008; Petrović et al., 2012).

Digestive effects of forages depend on plant species, stage of maturity, method of preservation and diet composition. Forage quality is first determined by content of useable energy, crude protein and its fractions - rumen degradable and undegradable protein, neutral detergent fiber-NDF and acid detergent fiber-ADF. The ensiling process represents storage and conserving forage system that includes mechanical and biological processes for preservation of quality and feeding characteristics of silage, maintaining the content of dry matter-DM, energy, protein and digestible fiber. Besides the chemical composition, physical effectiveness is basic parameter that influences nutritional value and quality of forages in ruminant nutrition (Stojanović et al., 2009).

Insufficient particle size of diet for dairy cows decreases ruminal acetate to propionate ratio, milk fat content and feed conversion efficiency, with possible causing ruminal acidosis, paraceratosis, lameness, dislocation of abomasus and fat cow syndrome (Stojanović et al., 2011).

Intake of diet with deficit of effective fiber cause disturbance of ruminal function, and ruminal fermentation. In opposite, excessive content of long and coarse forage particles in total mixed rations for dairy cows results in decreased feed intake and digestibility of consumed DM, and negatively affects cow’s energy balance (Allen, 2000).

Fine chopping of roughage (corn silage, grass silage, alfalfa silage and barley silage) to a theoretical particle size of 4 to 6 mm adversely affect rumination activity and rumen fermentation in diets for lactating cows containing relatively large amounts of concentrate (50 to 60 % DM). Lowering the particle size of forages decreases ruminal pH and fiber degradation. Finally, moderate decreasing the theoretical particle size of forages to approximately 10 to 15 mm promotes ruminal digestion (Zebeli et al., 2012).

Materials and methods

The experiments were performed in the first decade of June 2014, at two locations planted with alfalfa in the second year of exploitation. The study is focused on preparation of alfalfa haylage in the second mowing.

Domestic variety of alfalfa "Banat" seeded at first location, was harvested with the self-propelled forage harvesters Krone Big X 700 and Krone Big X 500, equipped with pick-up adapters. Average operational speeds were 6.1 and 6.9 km/h, respectively. The experiment was performed at flat terrain, parcel T-10 (25 ha) of "PKB" corporation, farm "Mladost - Jabučki Rit", Belgrade - GPS coordinates (44^o 55' 59" N, 20^o 33' 3" E). Achieved yield of wilted chopped mass was 3.2 t/ha.

The second domestic variety of alfalfa, "Morava", was seeded at the parcel "Directorate" (8 ha) of the "Almex" corporation, farm "Kačarevo" AD, Pančevo - GPS coordinates (44^o 54' 44" N, 20^o 38' 15" E). During the second experiment, this crop was harvested with the self-propelled forage harvester Claas Jaguar 950, equipped with pick-up adapter. Average operational speed was 9.8 km/h and yield of wilted chopped mass amounted to 8.3 t/ha.

Identical technollogy of preparation alfalfa haylage was applied at both locations. Before harvesting, plant was mowed by self-propelled mower, at the small-bud growth stage and average green mass humidity of about 70%. Partially wilted crop mass was gathered into swath tracks. Wilting process of the crop collected in swaths was finished when dry matter content was average 49 % ("PKB location ") and 38 % ("Almex" location). Under these conditions, mass was chopped with self-propelled forage harvesters, and ensiled. Technical characteristics of the applied machines are given in Table 1.

Table 1. *Technical characteristics of examined self-propelled forage harvesters*

Parameters	Unit	Type of silage harvesters		
		Claas JAGUAR 950	Krone BiG X 700	Krone BiG X 500
Engine		OM 502 LA V8 16 l	MAN D2868 V8 16 l	OM 460 LA R6 12.8 l
Exhaust gas standard		TIER 4i	TIER 2	TIER 3
Max. power (ECE R120)	kW	440	570	375
Feeder width / height	mm	730/180	760/170	760/170
Cutting cylinder width / diameter	mm	750/630	800/660	800/660
Number of knives on the drum		24	28	28
Corn cracker diameter	mm	250	250	250
Spout rotation angle		210°/225°	210°	210°
Base unit weight without header	kg	12,500	14,350	13,000
Particle length setting on plot	mm	44	10	8

Particle lengths of the forage samples were determined by hand separating and sieving of samples, acquired from the transport trailer, and classification in the appropriate length fractions.

Results and discussion

Elementary descriptive statistics parameters of mass distributions, related to length of chopped haylage particles are given in Table 2.

Table 2. *Descriptive statistics of alfalfa cut length distribution*

Krone Big X 700 - length setting 10 mm							
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Average
MEAN L (mm)	m_L	22.63	22.99	25.74	22.20	24.68	23.65
REL_ERR[MEAN L] (%)	ε_{mL}	126.32	129.87	157.39	122.00	146.83	136.48
ABS_ERR[MEAN L] (mm)	Δm_L	12.63	12.99	15.74	12.20	14.68	13.65
ST.DEV.[L] (mm)	σ_L	16.61	17.11	17.48	15.88	17.81	17.04
COEF. VAR. [L] (%)	C_{VL}	73.39	74.45	67.89	71.53	72.15	72.07
Claas Jaguar 950 - length setting 44 mm							
MEAN L (mm)	m_L	36.38	32.22	33.00	34.92	32.28	33.76
REL_ERR[MEAN L] (%)	ε_{mL}	-17.31	-26.78	-24.99	-20.65	-26.64	-23.27
ABS_ERR[MEAN L] (mm)	Δm_L	-7.62	-11.78	-11.00	-9.08	-11.72	-10.24
ST.DEV.[L] (mm)	σ_L	18.25	18.12	18.48	18.07	18.28	18.31
COEF. VAR. [L] (%)	C_{VL}	50.16	56.25	55.98	51.75	56.62	54.24
Krone Big X 500 - length setting 8 mm							
MEAN L (mm)	m_L	22.91	19.86	21.83	26.04	23.07	22.74
REL_ERR[MEAN L] (%)	ε_{mL}	186.39	148.20	172.90	225.45	188.35	184.26
ABS_ERR[MEAN L] (mm)	Δm_L	14.91	11.86	13.83	18.04	15.07	14.74
ST.DEV.[L] (mm)	σ_L	17.18	14.15	16.56	17.62	17.00	16.67
COEF. VAR. [L] (%)	C_{VL}	74.97	71.26	75.87	67.66	73.70	73.30

MEAN L - Mean length; REL_ERR[MEAN L] - Relative error of mean cut length with respect to preset value; ABS_ERR[MEAN L] - Absolute error of mean cut length with respect to preset value; ST.DEV.[L] - Standard deviation of cut length distribution; COEF. VAR. [L] - Variation coefficient of cut length distribution.

In addition, haylage mass frequency distributions $\mathbf{f_m}$ (%) of particles cut lengths $\mathbf{L_D}$ (mm), chopped by three harvesters are presented in figures 1, 2 and 3.

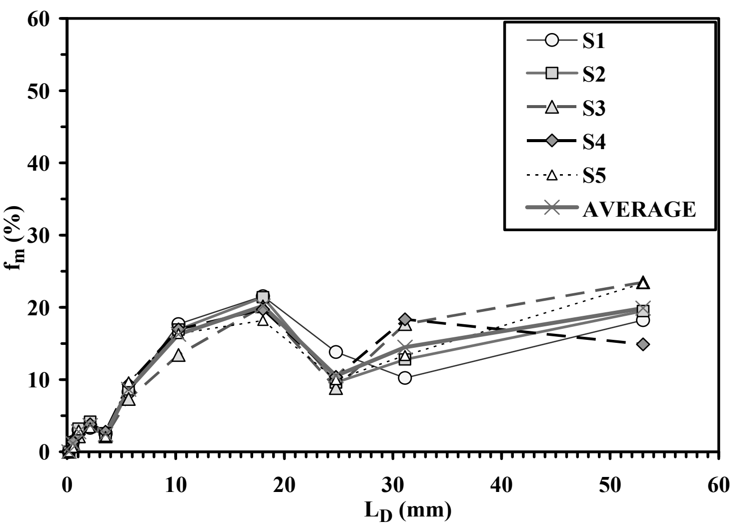

Fig. 1 *Mass % distribution of lucerne haylage cut lengths, chopped by Krone Big X 700*

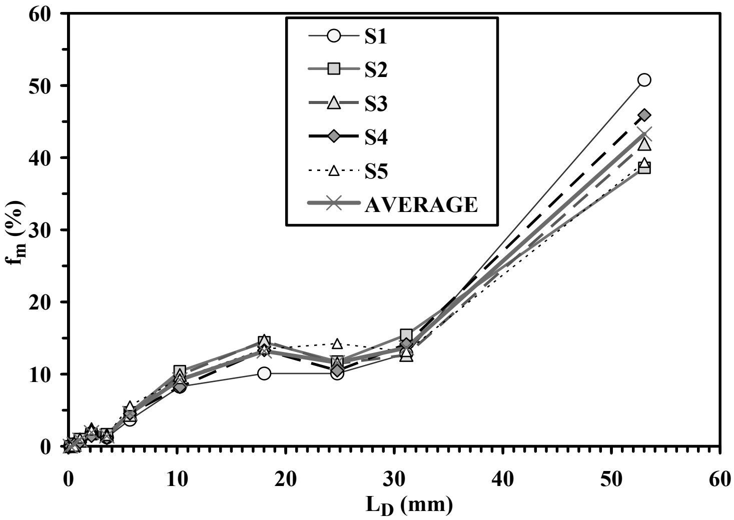

Fig. 2 *Mass % distribution of lucerne haylage cut lengths chopped by Claas Jaguar 950*

In general, it is evident from these figures that length frequency distributions are characterised by high mass percentage of the fraction comprehending the largest particles.

This evidence is in full agreement with reports of many other authors. As it was expected, general shapes of cut length distributions of haylage particles produced by combines Krone Big X 500 and Krone Big X 700 are similar, while Claas Jaguar 950 generates distributions of different shape. More precisely, frequency distributions related to Krone combines possess two extreme values, while the frequency of particles length distribution generally raise toward longest particles in the case of Class Jaguar 950 harvester.

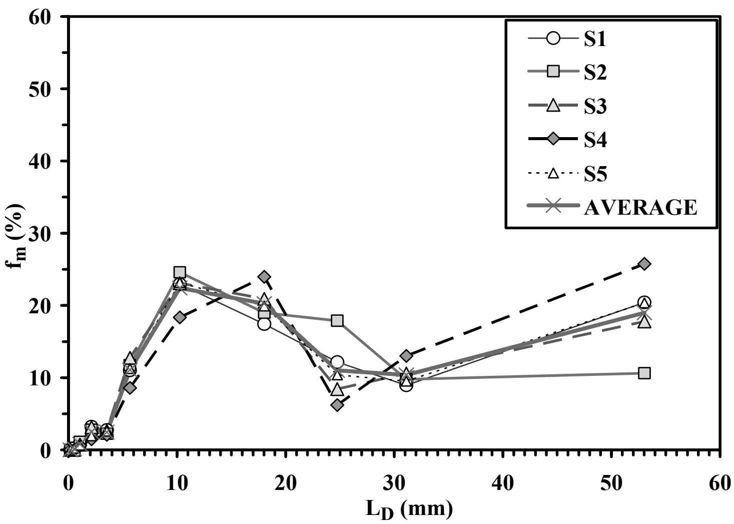

Fig. 3 *Mass % distribution of lucerne haylage cut lengths, chopped by Krone Big X 500*

Absolute errors of chopped particles mean lengths (mean value calculated on the basis of all five samples) were 13.65 mm, 10.24 mm and 14.74 mm, for combines Krone Big X 700, Claas Jaguar 950 and Krone Big X 500, respectively. Relative errors of particles cutting, defined with respect to the mean lengths, were 136.48 %, 23.27 % and 184.26 %, for combines Krone Big X 700, Claas Jaguar 950 and Krone Big X 500, respectively. For these three combines, standard deviations of cutting lengths were 17.04 mm, 18.31 mm, 16.67 mm, while the variation coefficients were 72.07 %, 54.24 % and 73.30 mm, respectively.

This means that combine Class Jaguar 950 achieved the mean chopping length closest to preset value. In addition, the variation coefficient of chopped particles length distribution was smallest, what means the highest concentration of length distribution around the mean value. Consequently, it follows that second harvester, produced by Class, provided the highest cutting precision with respect to preset value of chopping length.

Conclusion

The primary goal of farm management in this region is to facilitate further haylage compression in silos and haylage distribution within the livestock buildings after harvesting. Following this kind of approach, Serbian farming practice does not follow strictly the recommendations on the optimal length distribution of forage fractions, related to nutritional forage properties. During the presented experiment, real conditions that characterise current forage production of this kind have been followed.

Physical characteristics of rations for ruminants are influenced by dietary forage to concentrate ratio, type of forages and concentrates, and mean particle size of feeds. The particle length distribution of any forage is important parameter for ruminant’s diet formulation, especially for dairy cattle. During silage production, harvest considerations should be focused to obtaining an appropriate particle size distribution of the ensiling crop.

Within the framework of the examined forage harvesters, Claas Jaguar 950 achieved a slightly shorter average mean length of particles from preset value, while harvesters Krone Big X 700 and Krone Big X 500 made several times longer average mean length of chopped particles with respect to the specified (theoretical) length.

Possible explanation of this fact, regarding the conditions at the parcels, can be found in the difference of wilted mass moisture on field; Krone's combines were used at lower moisture content of wilted mass in relation to combine Claas.

Other causes for the above results, which are not covered by this study, can be found in the constructional solutions and adjustment of the silage harvesters, as well as the reliability of individual machines. In further research it should be determined what constructional solutions and adjustment of the different silage harvesters could effect that considerable difference regarding the cut length of the haylage particles.

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