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Effects of Different Harvesting Methods and Bale Shape on Hay Quality

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In this work, the quality of hay harvested with different harvesters and bailed in different shapes was investigated. In addition, the fuel consumption of the methods were evaluated. Harvesting was achieved by using a mower and a disc mower with conditioner. The forage was baled in shape of cylindrical and prismatic by the bale machines. The mixture of caramba+berseem clover was used as forage material. The tests were carried out according to split block design with three replications.
The quality of the material was evaluated in terms of dry matter (DM), pH, crude protein (CP), asit detergent fiber (ADF) and neutral detergent fiber (NDF). Also, the fuel consumption of machines was compared. The type of harvester was found to be statically significant on pH ($p \leq .05$) and fuel consumption ($p \leq .01$). The bale machine was significantly effective on DM ($P \leq .01$), bale weight ($P \leq .01$), fuel consumption ($P \leq .01$), CP ($P \leq .05$) and ADF ($P \leq .05$). The method of prismatic baled after harvesting with mower gave better results in terms of both quality and cost.

1. Introduction

Hay which is one of the roughage sources, has to be found especially on the ruminant diet, though its feeding value is lower than silage and haylage. In order to protect ruminant health, it is necessary to be fed cellulose and protein rich roughage for livestock. It is known that some mechanization applications which is used for hay supplement affect hay quality and cause losses. In the periods when livestock farms cannot supply silage, the hay plays a role of compensatory. Therefore, conservation of hay quality at maximum level is an important issue in terms of animal health and profitability. The most important preference reason of roughage for producers is that they are abundant, quality and cheap.
Since, the region has a temperate climate, the haymaking remains the major process for conserving roughage in the Cukurova region. In generally, hay is baled at moisture content 15-18%. The first goal in haymaking is to maintain the dry matter yield and nutrient content of standing forage. Physical, biological, and chemical processes during harvest and storage cause dry matter and nutrient losses. However, this issue is not considered importantly by producers in Turkey. Good management and proper equipment usage can help reducing these losses and preserve forage quality.
It has been revealed that the desired meat/milk yield cannot be provided in animals that are not fed with the suitable roughage and concentrate (Karadavut et all., 2011). The purpose of harvesting roughage is to increase the quality and dry matter content and to reduce losses. It is reported that DM losses varied in between 5% and 30% depending on moisture content at the harvest time (Ball et all, 1996; Schoeder, 2004). DM, CP and carotene losses starting immediately after harvesting can be examined bi-directionally as biologically and mechanically. Polak et all. (2006) emphasized that harvesting machines affect the DM and metabolic energy change, and that conditioner type machines will be useful to ensure a rapid rate of dry matter.
Bastaban and Ülgen (1982) emphasized that the increase of DM causes a significant increase in the loss of CP. In particular, the loss of CP increased from 1.33% to 2.51% with approximately 10% decrease of moisture content of clover. However, it is known that the balling of some forages which has higher than 25-30% of moisture content accelerates the mold formation. Moreover, the amount of digestible protein and carbohydrate

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in leaves is higher than in stems. For this reason, it is important to prevent leaf losses (Russell and Jhonson, 2014). Since harvesting systems of roughage include drying process subjected to completely meteorological factors, the quantitative and qualitive losses of the system reach the big amounts. Knowing the amount of losses and the factors affecting this provides some alternatives according to the methods and machines used in the production system (Bastaban et all., 1998). The losses depend on the using machines during harvesting, conditioning, ventilation, baling and transporting related with operation parameters and type of these machines (Rotz, 1995).

Hay production processes include cutting, conditioning, packaging, handling, storage, and preservation. Each of them affect the forage quality, resource requirements, and hay production costs. Therefore, the harvesting and balling techniques to be used must be specialized according to the forage. In this work, the quality of hay harvested with different harvesters and bailed in different shapes was investigated. In addition, the fuel consumption of the methods were evaluated.

2. Materials and methods

The study was conducted Eastern Mediterranean Agricultural Research Institute, Adana, Turkey (Cukurova Region). It was carried out conditions of Cukurova Region between November 2014 and June 2015. The average climatic values for research duration were given in Table 1. The soil characteristics of the experimental area were sandy-loam and alkaline (pH:7.86-7.75). Organic matter, lime content, potassium and phosphorus in the experimental area were 2.28-2.41%, 15.9-16.3%, 109.2-123.3 kg da^{-1}, 4.32-5.16 kg da^{-1}, respectively.

Table 1 Average climatic values of Cukurova Region during research period

Months	Temp. (^{o}C)	Rainfall (mm)	R. Humidity (%)
November, 2014	15.1	36.06	54.7
December, 2014	13.4	50.05	71.6
January, 2015	9.7	72.39	66.9
February, 2015	11.3	90.68	70.1
March, 2015	14.0	148.80	64.9
April, 2015	16.9	7.80	62.5
May, 2015	22.5	81.02	64.4
Juna, 2015	24.2	0.00	69.1
Total Rainfail and Average of Tempeture Values-R. Humidity	15.8	486.8	65.5

Mixture of caramba-berseem clover (Lolium multiform cv Caramba-Trifolium alexandrinum L.) was used as forage material in the experiment (Figure 1). According to Ozkul et. all.(2012), caramba can be an alternative plant in animal nutrition. It is annual forage grass. Although it is consumed in the form of green grass by grazing, the dried or silage form also can be used in ruminant nutrition. Berseem clover is one of forage legume. This mixture is new roughage for the Cukurova Region. Plants were harvested at the end of flowering stage. They were dried on the field until their moisture content reached 80-85%. The properties of the mixture are given in Table 2. The average yield of the material was calculated as 5 465.2 kg da^{-1}.

Figure 1. The mixture of caramba-berseem clover

Table 2. The properties of the mixture and plant length

Content of mixture	The properties of the mixture (m^2)		Plant length (cm)
	kg	%	
Caramba	4.094	25	132.7
Berseem clover	1.371	75	114.4
Total	5.465	100	

Harvesting of forage was achieved by using two different machines: mower and disc mower with conditioner. Then after, they were baled in prismatic and cylindrical shape. After storage under awning for two months, hay samples were taken for quality evaluation.

The Ford 6600 model tractor with 58 kW was used in the field. The fuel consumption of tractor was measured by using two flowmeters (Macnaught M05, Macnaught Pty. Ltd., Australia). One of the flowmeter was placed between fuel tank and injection on the outbound line and the other was connected to the return line. The difference between two flowmeters gave the fuel consumption.

Some technical characteristics of machines were presented in Table 3. The machines used in the experiment can be seen in Figure 2 and 3.

Table 3. Some technical characteristics of machines

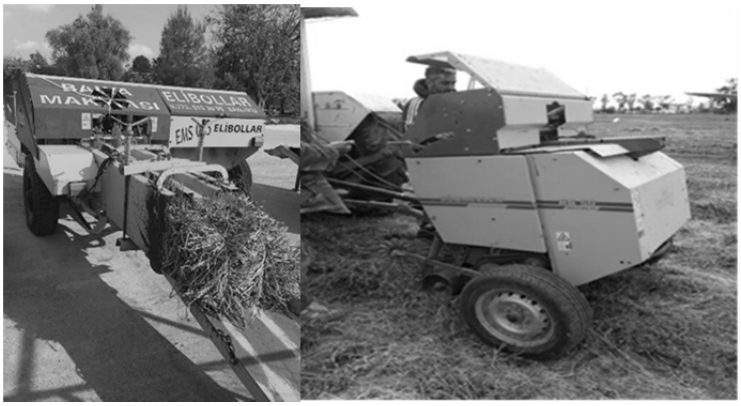
Technical properties	Harvester	
	Disc mower with conditioner	Mower
Number of disk	5	2
Working width (cm)	240	165
Mass (kg)	500	360
	Bale machine	
	Prismatic	Cylindrical
Bale size (cm)	36x30x135	50x70
Mass of bale (kg)	25-30	25-30
Mass (kg)	1600	540

The quality of the material was evaluated in terms of DM, pH, CP, ADF and NDF. The DM content of forage was determined by drying to constant weight at 105 °C according to the ASAE standards. Nitrogen (N) content was measured using the Kjeldahl method. The pH values of hays were obtained as reported by Chen et all. (1997). The CP was calculated as Nx6.25 (AOAC, 1990). The ADF and NDF were determined as suggested Van Soest et all (1991) by using ANKOM fiber analyzer.

The tests were carried out according to split block design with three replications. The statical analysis were done by JMP Statical (Version 7) software. The methods were compared according to standards assigned by Hay Market Task Force of American Forage and Grassland Council (Mayouf and Arbouche, 2014; Russel, 2014). In this work, the methods for supplying prismatic and cylindrical bales which was 25-30 kg in weight for small farms compared in terms of some operational parameters and hay quality.

(a) (b)

Figure 2. Mower (a) and disc mower with conditioner (b)



(a) (b)

Figure 3. Prismatic (a) and cylindrical (b) bale machine

3. Results and discussion

The test results were tabulated in Table 4 and 5. The type of harvester was found to be statically significant on pH ($p \leq .05$) and fuel consumption ($p \leq .01$). It was determined that the pH level of forage harvested by disc mower with conditioner (5.87) was 5.6% lower than that of harvested by the mower (6.22). This result can be assessed positively in terms of quality. When the harvesters were evaluated in terms of fuel consumption, it was obtained that the mower consumed about 50% less fuel then the disc mower with conditioner. The bale machine was significantly effective on DM ($P \leq .01$), bale weight ($P \leq .01$), fuel consumption ($P \leq .01$), CP ($P \leq .05$) and ADF ($P \leq .05$) while it has no effect on pH and NDF. According to these results, it is possible to say that the bale machine in other words, the bale shape has a considerable effect on the quality of hay.

Table 4. Statical analysis of some quality parameters.

Parameters	DM (%)	Bale weight (kg)	pH	Bale density (kg m^{-3})	CP (%)	ADF (%)	NDF (%)
Harvester							
Mower	85.3	20.96	6.22^{a}	116.58	14.71	39.22	51.52
Disc mower (conditioner)	85.6	20.75	5.87^{b}	118.74	14.22	36.76	50.60
$LSD_{(0.05)}$	-	-	0.28	-	-	-	-
Bale machine							
Prismatic	82.3^{b}	22.55^{a}	6.02	108.71^{b}	15.64^{a}	40.70^{a}	51.62
Cylindrical	88.6^{a}	19.15^{b}	6.07	126.61^{a}	13.28^{b}	35.28^{b}	50.49
$LSD_{(0.05)}$	1.07	0.69	-	7.94	1.73	5.5	-
CV(%)	0.89	2.35	3.37	4.78	8.47	10.4	10.8
Harvester	0.47^{ns}	0.47^{ns}	0.023^{*}	0.53^{ns}	0.51^{ns}	0.32^{ns}	0.78^{ns}
Bale machine	$<.0001^{**}$	$<.0001^{**}$	0.63^{ns}	0.0015^{**}	0.01^{*}	0.05^{*}	0.73^{ns}
Harvester x Bale machine	0.47^{ns}	0.0006^{**}	0.56^{ns}	0.0074^{**}	0.94^{ns}	0.84^{ns}	0.28^{ns}

In each column, means with the same letters are not significantly different at .01 level of significance using Duncan's Multiple Range Test

CP is one of the most important values in quality evaluation. This value changed according to the bale shape and it was determined that the prismatic bales had higher value than the cylindrical one. The reason why the ratio of CP in cylindrical bales is about 15% lower can be attributed to the machine effect on plant during baling process. The amount of the leaf affects the CP ratio directly. If the amount of leaves is low, the CP ratio may decrease. In the duration of baling, dried and fragile leaves can crush due to process of the taking the material into the machine and rotation movement of the material in the bale chamber. The cylindrical bale weight (19.15 kg $bale^{-1}$) was found to be 15% less than prismatic bale (22.55 kg $bale^{-1}$), while the bale density was about 14% higher in prismatic bales. In addition, it was estimated that since the cylindrical bales were dense, they had higher internal temperature. Their CP quality and quantity may decrease depending on this condition. Gul et all. (2008) reported that as the size of cylindrical bale increased the fluctuations in

temperature and humidity reduced and accordingly the cellulose and protein losses rise in comparison the prismatic bales with cylindrical ones.

It was observed that more leaf loss from the outer surface of cylindrical bales occurred during the handling, transport and storage operations. However, the leafy parts remains at the inner section of prismatic bales and for this reason, lower leaf losses in prismatic bales were obtained. In terms of ADF, the situation was exactly opposite. The ADF ratio in cylindrical bales (35.28%) was low as required while slightly higher in prismatic bales (40.7%).

Fuel consumption of bale machines varied statistically (Table 5). The fuel consumption of the cylindrical baler (0.47 l da^{-1}) was about 30% higher than the prismatic baler (0.33 l da^{-1}). This is a major disadvantage for the cylindrical baler, as the priority factor that determines the cost of making hay is fuel consumption. However, it has been emphasized that the working performance of the prismatic baler was higher than that of the cylindrical baler but it was stated that cylindrical bales are better for the loading and unloading working efficiency (Guler, 1997).

Table 5. Fuel consumption of machines

Parameters	Harvester (l da^{-1})	Bale machine (l da^{-1})	Total fuel consumption (l da^{-1})
Harvester			
Mower	0.69^{b}	0.38	1.08^{b}
Disc mower (conditioner)	1.41^{a}	0.41	1.83^{a}
$LSD_{(0.05)}$	0.05	-	0.1
Bale machine			
Prismatic	1.05	0.33^{b}	1.38^{b}
Cylindrical	1.05	0.47^{a}	1.52^{a}
$LSD_{(0.05)}$	-	0.068	0.1
CV(%)	3.42	11.9	4.87
Harvester	$<.0001^{**}$	0.34^{ns}	$<.0001^{**}$
Bale machine	1^{ns}	0.0025^{**}	0.01^{*}
Harvester x Bale machine	1^{ns}	0.04^{*}	0.13^{ns}

In each column, means with the same letters are not significantly different at .01 level of significance using Duncan's Multiple Range Test

4. Conclusions

The selection of harvester and bale machines used to supply hay may vary depending on the crop and region conditions. There are benefits to plan hay making considering the climate conditions. However, it should be noted that any low-cost system cannot be used tom supply quality forage.

With a general approach, the disc mower with conditioner which increases the amount of DM due to its crushing effect can be proposed for rainy region at harvesting period. Results showed that prismatic baling after harvesting with mover was more advantageous in terms of cost (fuel consumption of harvester and bale machine and purchasing costs of the machines) and that a good quality forage can be supplied in terms of CP in Cukurova region, Turkey where the research was conducted. However, it can be said that higher ADF ratio can be a disadvantage for this method. But, considering the quality standards of legume and grass forage, in terms of CP and ADF values, all methods were found to be in second quality level. Consequently, although the results obtained with disc mower with conditioner was reasonable, it can be pointed that the method of prismatic baled after harvesting with mower was better in terms of both quality and cost.

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