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Baled Alfalfa Losses, Nutrient Values, and Storability Affected by Bale Density and Alfalfa Moisture Content

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Authors' contributions

This work was carried out in collaboration between both authors. Author SA designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Author AK managed the analyses of the study. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: In this study, effects of bale density and alfalfa moisture content on alfalfa losses, nutrient values, and storability of baled alfalfa were evaluated.
Study design: The research was conducted in the form of a split-plot experimental design with three replications. Alfalfa moisture content with three levels was considered as main plots, and alfalfa bale density with four levels was considered as subplots.
Place and Duration of Study: This study was conducted on an alfalfa farm located in Eghlid township, Fars province, Iran from September 2008 to September 2010.
Methodology: The research was conducted in the form of a split-plot experimental design with three replications. Main plots were alfalfa moisture content levels including 14 to 17%, 17 to 20%,

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and 20 to 23% (wb), and subplots were bale density levels namely 110 to 120 kg/m^3, 120 to 130 kg/m^3, 130 to 140 kg/m^3, and 140 to 150 kg/m^3. Parameters including dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and aflatoxin were measured at the beginning and after six months of storing the bales. Alfalfa losses were also measured in the baling and transportation processes. Collected data were analyzed using SAS statistics program and Duncan multiple range test was used to compare the treatments means.

Results: Results revealed that alfalfa moisture content had significant effect on alfalfa losses in baler pickup system (*P*=.05) and transportation losses (*P*=.01) so that baling alfalfa at the moisture content of 20 to 23% reduced alfalfa losses in baler pickup and transportation process for 40% and 70%, respectively compared to baling at 14 to 17% of moisture content. Results also showed that alfalfa can be baled at the moisture content range of 20 to 23% (wb) without losing its nutrient values and being infected by aflatoxin in the storage for a storing period of six months.

Conclusion: Results of this study revealed that:

1. Alfalfa moisture content has a significant effect on the alfalfa losses during the baling and transportation process so that alfalfa losses decrease with increasing moisture content.
2. Alfalfa losses during the baling and transportation process are significantly affected by bale density in such a way that higher losses occur at the looser bales.
3. Alfalfa can be baled at the moisture content range of 20 to 23 % (wb) and the bale density of 140 to 150 kg/m^3 without losing its nutrient values and being infected by aflatoxin in the storage for a storing period of six months.

Keywords: Alfalfa dry matter; crude protein; acid detergent fiber; neutral detergent fiber; aflatoxin.

1. INTRODUCTION

About 600 thousand hectares of alfalfa is planted in Iran every year and 4.5 million tones alfalfa are produced. According to the results of research conducted by Rotz and Abrams [1], about 25% of the produced alfalfa is lost during the harvesting and post-harvesting processes. Most of these losses happen during the baling process. Shinners et al. [2] compared two small rectangular balers with different feeding system from the viewpoint of alfalfa losses. They reported that baler with bottom fed chamber had lower losses in the compression chamber and pickup system compared to side fed chamber. Shinners et al. [3] showed that alfalfa losses in the pickup system of small rectangular, mid-size rectangular, and round balers were 0.4, 0.7, and 2.61%, respectively. They also reported the bale chamber losses of 0.7, 1.6, and 1.6% for the small rectangular, mid-size rectangular, and round balers, respectively. Alfalfa moisture content at the baling time has a significant effect on the losses during the baling process. Buckmaster et al. [4] reported that losses in the pickup system of baler increased from 3% to 6% when the moisture content decreased from 30% to 12%. Pitt [5] measured the pickup losses of 2% for the alfalfa moisture content of higher than 30%, and pickup losses of 4% for the alfalfa moisture content of lower than 30%. Losses in the pickup system of baler were reported 1.8% by Rotz and Abrams [1], 1.8 to 2.8% by Straub et al. [6], 2 to 2.4% by Koegel et al. [7], 1 to 3% by Whitney [8]. Rotz and Abrams [1] reported 1.1% for the bale chamber losses at the alfalfa moisture content of 20.5%. Bale chamber losses of 4.8 and 7.3% were reported by Straub et al. [6] for the moisture content of 29 and 21%, respectively. Koegel et al. [7] measured the loss of 2.8% for the bale chamber at alfalfa moisture content of 18%. In addition to quantity losses, quality losses also occur during baling and postharvest process of alfalfa forage. Rotz [9] reported that hay quality and quantity Losses were reduced when dry hay was stored in a shed, but these losses could be 15% or more when dry hay was stored outside. Based on Orloff and Putnam report [10], the maturity stage at which alfalfa forage is harvested is an effective factor on harvesting alfalfa quality and yield. Coblentz et al. [11] reported that alfalfa moisture content at baling time and storage period had also a significant effect on alfalfa quality changes during storage. Results of a research conducted by Shinners et al. [12] shows that bale shape (square or round) and bale wrapping method have no significant effect on dry matter and nutrient losses of baled alfalfa. Buckmaster et al. [4] reported that alfalfa losses during the harvesting and post-harvesting process reduce the farmer total income for 12060 $/year. Corre and Bull [13] showed that big bales had more heating problem compared to small bales. They also reported that transportation of big bales was more convenient and had less costs compared to small bales. In this study, the effect of bale density and alfalfa moisture content on the alfalfa nutrient values bales storability, and alfalfa losses were evaluated.

2. MATERIALS AND METHODS

In this study, the effect of bale density and alfalfa moisture content on the alfalfa losses, alfalfa nutrient values, and bale storability was determined. The research was conducted in the form of a split-plot experimental design with three replications. Moisture content with three levels was considered as main plots, and bale density with four levels was considered as subplots. Moisture levels were including; 14 to 17%, 17 to 20%, and 20 to 23% (wb) and bale density levels were 110 to 120 kg/m^3, 120 to 130 kg/m^3, 130 to 140 kg/m^3, and 140 to 150 kg/m^3. Treatment containing bale density of 120 to 130 kg/m^3 and moisture content of 14 to 17% was considered as control treatment. Parameters including dry matter (DM), crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL), and aflatoxin were measured at the beginning and after six months of storing the bales. Alfalfa losses were also measured in the baling and transportation processes. Collected data were analyzed using SAS statistics program and Duncan multiple range test was used to compare the treatments means.

2.1 Measurement Methods

2.1.1 Moisture content

Moisture content of samples was determined using ASAE standard [14]. In this method, a sample weighing at least 25 gr is dried in oven for 24 hours at the temperature of 103 degrees centigrade, and moisture content (%wb) is calculated using the following equation (1):

$$mc = \frac{M_w - M_D}{M_w} \times 100 \quad (1)$$

Where,

mc = moisture content (%wb),
M_w = wet sample weight (gr) and
M_D = dry sample weight (gr).

2.1.2 Bale density

Different density levels were obtained by changing the position of a lever on the bale compression chamber which controls the bale density. After selecting the new position for the lever, the bale density was practically calculated by measuring bale dimensions and bale weight.

2.1.3 Baling losses

Alfalfa losses were measured in the baler pickup system and baler compression chamber during the baling process. Losses of pickup system were collected using a 0.5×0.5 m^2 frame from different points of the harvested crop rows. These losses were then separated to leaf and stem losses. To collect the losses of compression chamber, a plastic strip of 1.0×6.0 m^2 was laid flat on the ground underneath the bale compression chamber. The collected forage materials from the plastic strip were also separated to leaf and stem parts.

2.1.4 Transportation losses

Baled alfalfa was transferred to a storage which was about 250 km far from the farm. To measure alfalfa losses during transportation from farm to storage, bales were weighed before loading to truck on the farm and right after discharging in the storage. Alfalfa moisture content was also determined before loading and after unloading alfalfa bales. The difference between the dry mater weight of bales before loading and after discharge was considered as the transportation loss of each bale.

2.1.5 Nutrient values and aflatoxin

Nutrient values and aflatoxin as a criterion of alfalfa bales storability were measured using AOAC standard [15] at the beginning and the end of storing period (six months). The difference between the values of the measured parameters at the beginning and the end of storing period was used as the data for evaluation of nutrient values and storability of baled alfalfa.

3. RESULTS AND DISCUSSION

Results showed that alfalfa moisture content at the baling time had no significant effect on the leaf and stem losses of bale compression chamber (Table 1). However; leaf and stem losses of baler compression chamber at the moisture content of 14 to 17% were higher than those of the moisture contents of 17 to 20% and 20 to 23%. Moisture content had significant effect on the leaf losses of baler pickup system (*P*= .05) while; stem losses in the baler pickup system was not affected by alfalfa moisture content (Table 2). Leaf losses in the pickup system at the moisture content of 14 to 17% were the maximum and at the moisture content of 20 to 23% were the minimum. Since leaf is the most sensitive part of alfalfa to the moisture content, it is logical to have the higher losses in the pickup system at the lower levels of alfalfa moisture content. Inverse effect of alfalfa moisture content on the losses of baler pickup system has been also reported in the privious works [4,5].

Results of bale density effect on the leaf and stem losses of baler compression chamber are presented in Table 3. These results showed that leaf and stem losses in the baler compression chamber were significantly affected by bale density (*P*=.05). Bale density of 120 to 130 kg/m^3 which was the controlling bale density, had the highest leaf and stem losses in the compression chamber. Bale density had no significant effect on the leaf and stem losses of pickup system which was expected (Table 4).

Results of alfalfa losses during the transportation process showed that alfalfa moisture content had a significant effect (*P*= .05) on the losses of transportation (Table 5). Transportation losses were the highest at the moisture content of 14 to 17% since alfalfa with lower moisture content was more sensitive to the impact compared to the high moisture alfalfa. There was no significant difference between the losses of transportation at the moisture levels of 17 to 20% and 20 to 23%. Results also revealed that transportation losses were not significantly affected by the bale density.

Table 1. Effect of alfalfa moisture content on the losses of baler compression chamber

Moisture content (%wb)	Leaf losses in compression chamber (%)	Stem losses in compression chamber (%)	Total (%)
14-17	2.7 a	0.3 a	3.0 a
17-20	2.5 a	0.2 a	2.7 a
20-23	1.9 a	0.2 a	2.1 a

Culonms with common letters are not significantly different.

Table 2. Effect of alfalfa moisture content on the losses of baler pickup system

Moisture content (%wb)	Leaf losses in pickup (%)	Stem losses in pickup (%)	Total (%)
14-17	0.7 a	0.3 a	1.0 a
17-20	0.5 b	0.2 a	0.7 b
20-23	0.4 c	0.2 a	0.6 c

Culonms with common letters are not significantly different.

Table 3. Effect of bale density on the losses of baler compression chamber

Bale density (kg/m^3)	Leaf losses in compression chamber (%)	Stem losses in compression chamber (%)	Total (%)
110-120	2. 7 ab	0.3 ab	3.0 a
120-130	3.0 a	0.3 a	3. 3 a
130-140	1. 8 c	0.2 b	2.0 b
140-150	2.0 bc	0.2 b	2.2 b

Culonms with common letters are not significantly different.

Table 4. Effect of bale density on the losses of baler pickup system

Bale density (kg/m^3)	Leaf losses in pickup (%)	Stem losses in pickup (%)	Total (%)
110-120	0.7 a	0.2 a	0.9 a
120-130	0.5 a	0.2 a	0.7 a
130-140	0.4 a	0.2 a	0.6 a
140-150	0.6 a	0.2 a	0.8 a

Culonms with common letters are not significantly different.

Table 5. Effect of alfalfa moisture content and bale density on the alfalfa losses during transportation

Bale density (kg/m^3)	Losses during transportation (%)	Moisture content (%wb)	Losses during transportation (%)
110-120	5.4 a	14-17	8.80 a
120-130	4.3 a	17-20	2.30 b
130-140	4.2 a	20-23	2.60 b
140-150	4.3 a		

Culonms with common letters are not significantly different.

Alfalfa total loss during the baling and transportation process is shown in Fig. 1. According to this Figure, moisture content had a significant effect on the alfalfa losses so that alfalfa losses decreased with increasig moisture content. The maximum amount of losses was occured at the moisture content of 14 to 17%, and the minimum amount was related to the moisture content of 20 to 23% however, there was no significant difference between the losses at the 17 to 20% and 20 to 23% ranges of moisture content.

Results also showed that bale density had a considerable effect on the alfalfa locess during the baling and transportation process (Fig. 2). Alfala loss had the maximum amount at the bale density range of 110 to 120 kg/m^3 and the minimum amount at the bale density rage of 130 to 140 kg/m^3.

Results indicated that dry matter, crude protein, and acid detergent lignin slightly decreased during the storing period (Table 6) . Dry matter reduction rate increased with the increase of moisture content while, rate of ADL reduction decreased with increasing alfalfa moisture content. The maximum CP reduction was occurred at the moisture content range of 17 to 20%. Neutral detergent fiber and acid detergent fiber increased with increasing alfalfa moisture content.

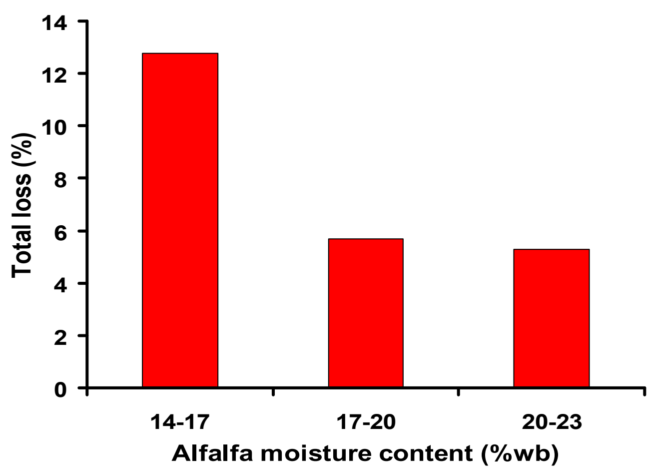

Fig. 1. Effect of moisture content on the alfalfa total losses during the baling and transportation processes

Table 6. Effect of moisture content on the changes of alfalfa nutrient values during the storing period

Moisture content (%wb)	Dry matter (%)	Crude protein (%)	NDF (%)	ADF (%)	ADL (%)
14-17	-0.68	-0.15	-0.18	5.27	-1.02
17-20	-0.95	-0.55	3.59	8.99	-0.18
20-23	-1.86	-0.17	8.52	6.99	0.11

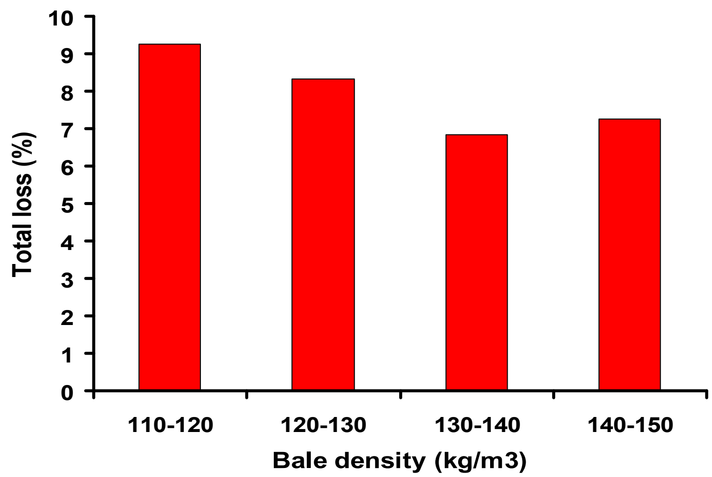

Fig. 2. Effect of bale density on the alfalfa total losses during the baling and transportation processes

Table 7. Effect of bale density on the changes of alfalfa nutrient values during the storing period

Bale density (kg/m^3)	Dry matter (%)	Crude protein (%)	NDF (%)	ADF (%)	ADL (%)
110-120	-0.81	-0.8	5.83	7.58	-1.29
120-130	-0.78	-0.79	4.08	8.39	0.91
130-140	-0.91	0.41	1.99	3.67	0.53
140-150	-2.14	0.01	4.01	8.69	-1.6

Dry matter reduction during the storing period increased with increasing bale density so that the maximum reduction was related to the bale density of 140 to 150 kg/m^3 (Table 7). Crude protein decreased in the low densities while, this parameter slightly increased in the higher densities. Neutral detergent fiber and acid detergent fiber at different bale densities increased during the storing period. This increment had the minimum amount at the bale density of 130 to 140 kg/m^3 while, there was no big difference between the NDF and ADF at the other bale densities. Acid detergent lignin decreased at the bale density ranges of 110 to 120 kg/m^3 and 140 to 150 kg/m^3 whereas, this parameter increased at the bale density ranges of 120 to 130 kg/m^3 and 130 to 140 kg/m^3.

Results of the effect of alfalfa moisture content on the aflatoxin variation during the storing period is shown in Table 8. These results showed that aflatoxin increased during the storing period at the moisture ranges of 17 to 20% and 20 to 23% while, this parameter slightly decreased at the moisture range of 14 to 17%. The maximum aflatoxin increment was observed at the moisture level of 20 to 23% which was expected. The maximum amount of aflatoxin increment was about 0.5 parts per billion (ppb) which was negligible compared to the allowable limit of aflatoxin in the animal feed (50 ppb).

Table 8. Effect of moisture content on the changes of aflatoxin in bales during the storing period

Moisture content (%wb)	Aflatoxin changes after six months (pbb)
14-17	-0.17
17-20	0.46
20-23	0.49

According to the results shown in Table 9, the aflatoxin increment at the different levels of bale densities was also negligible. Therefore, storing alfalfa bales at the high moisture content range (20 to 23%) even with the high bale density (140 to 150 kg/m^3) for a period of six months is applicable and safe from the view point of aflatoxin infection.

Table 9. Effect of bale density on the changes of aflatoxin in bales during the storing period

Bale density (kg/m^3)	Aflatoxin variability after six months (pbb)
110-120	0.5
120-130	0.01
130-140	0.12
140-150	0.40

4. CONCLUSIONS

Results of this study revealed that:

1. Alfalfa moisture content had significant effect on the alfalfa losses during the baling and transportation process so that alfalfa losses decreased with increasing moisture content.
2. Alfalfa losses during the baling and transportation process were significantly affected by bale density in such a way that higher losses were occurred at the looser bales.
3. Alfalfa can be baled at the moisture content range of 20 to 23 % (wb) and the bale density of 140 to 150 kg/m^3 without losing its nutrient values and being infected by aflatoxin in the storage for a storing period of six months.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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