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Full Length Research Paper

Effects of compaction and maturity stages on sunflower silage quality

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The aim of this research was to determine sunflower silage quality under different compaction conditions of the whole-plant sunflower (*Helianthus annuus L.*) harvested at three different maturity stages. These were the beginning of Anthesis, one-third Milk Line, and Black Line. Five compaction applications (control, vacuum and compaction with 150, 248 and 498 kPa) were carried out in the study. For this purpose, cylindrical plastic mini-silos (5.2 L) were used. The chopped forages were compacted in mini-silos at five pressure levels. Each treatment was ensiled for 50 days in cylindrical plastic mini-silos (5.2 L) silos with three replications. This study showed that compaction level and maturity stage had significant effects on silage quality ($p < 0.05$). The dry-matter content increased in the silages with maturity. The best results were observed when harvesting at the stage of one-third Milk Line and compaction with the level 498 kPa.

Key words: Sunflower silage, maturity stage, compaction level

INTRODUCTION

Sunflowers are generally planted for seed production. They are primarily used as cooking oil, in salads or as an ingredient in margarine. When sunflowers are grown as a second crop, they can be used as an alternative forage source when seeds do not have sufficient time to mature. Sunflower has drought tolerance, resistance to cold and heat, and adaptability to different climatic conditions (Putnam et al., 1990).

In order to obtain silage of good quality and of high nutritive value, the material should be cut at the right point of maturity. Tan and Tumer (1996) ensiled sunflowers at several stages of maturity and concluded that the final flowering stage was the best to make silage. The best harvest time for ensiling varied according to genotype (Gonçalves et al., 1999). The stage of maturity at harvest time and compaction level is a major factor in determining the nutritive value of silage (Toruk et al., 2009). Roy (2001) reported that density was an important factor in the final quality of silage. Compaction had a significant effect on increasing the density of corn (150 k DM/m^3 at 483 kPa, 139 kg DM/m^3 at 277 kPa with the September 22nd crop; 218 kg DM/m^3 at 483 kPa, 168 kg DM/m^3 at 119 kPa with the October 20th crop) but did not have a significant effect on the density of grass.

The feeding value of sunflower is approximately 80% of the value of corn silage. Whole-plant sunflower silage usually contains slightly more crude protein and considerably more fat than those of corn silage. Sunflower silage made from mature sunflower plants contains 10 to 12% crude protein compared to 8 to 9% commonly found in corn silage. In addition to a higher crude protein content, sunflower silage made from the varieties of oil seed contains 10 to 12% fat compared to 2 to 3% fat in corn silage (Garcia, 2002a).

In this study, it was aimed to determine the effect of the compaction levels on the nutritive value of sunflower silage at different maturity stages.

MATERIALS AND METHODS

Treatments and ensiling

The trials were conducted on the research area of Namik Kemal University, Faculty of Agriculture. Sunflower (*Helianthus annuus L.*) seed used was Meric F1 type which has medium maturation time and resistance to drought. Planting was performed by a pneumatic planting machine widely used in sunflower planting in April. Seeding

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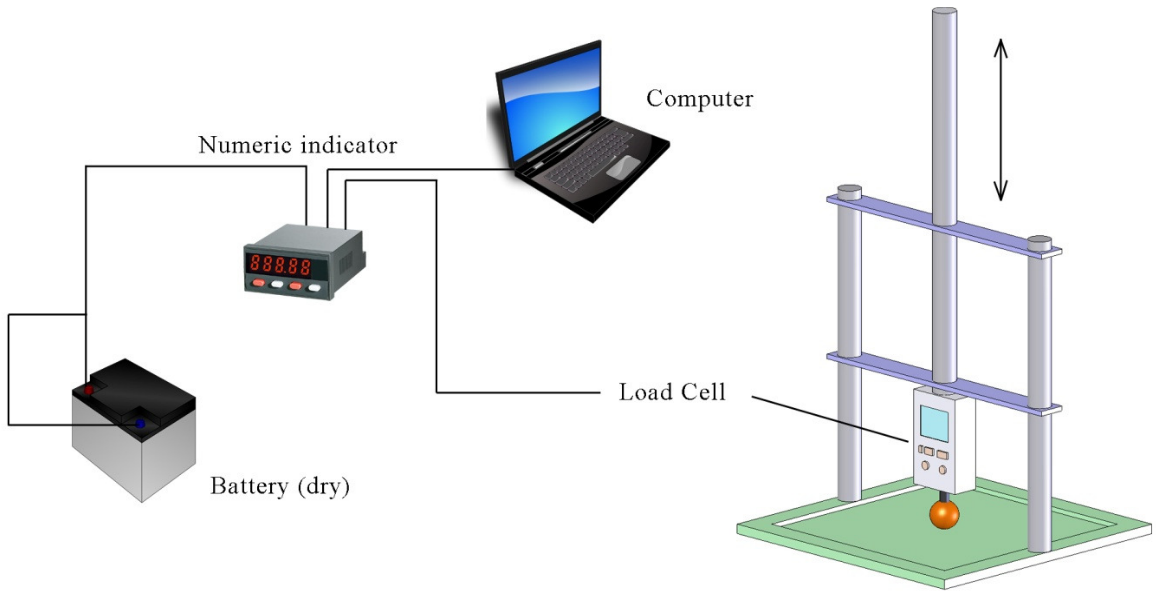

Figure 1. Trial set for compaction and load measure.

rate was 130000 seeds per hectare with 700 mm row width and with 80 mm planting depth (Anonymous, 1999; Kılıç, 1986). The crops were harvested and chopped by a forage harvesting machine. Harvesting was done at three stages of maturity. These were Beginning of Anthesis (BA), one-third Milk Line (ML), and Black Line (BL). The geometric mean particle length of sunflower was 10.5 mm (Brooking, 2002). The chopped materials were brought to the laboratory where mini-silos filling and compaction were done. Mini-silos are made of a PVC pipe with 100 mm inside diameter, 660 mm height, and a volume of 5.2 L (Roy, 2001).

The chopped material was filled with compaction and vacuum mechanisms. Trial set for compaction is shown in Figure 1. The set has mainly four units. These are battery (1), numeric indicator (2) for converting signals (coming from load cell) to numeric value, computer (3) for recording numeric values (coming from the numeric indicator) and load cell (4) for converting force to signal. ESIT, TCS 500 model load cell was employed by means of shear box method. A laptop computer and ProComm software were used to evaluate the numerical values (Toruk et al. 2009; Toruk and Koç, 2009).

Sunflower was ensiled with the following vacuum and compaction methods.

NC (control): without vacuum application and without compaction.
WV: vacuum application and without compaction.
C1: compaction by loading with the level of 150 kPa.
C2: compaction by loading with the level of 248 kPa.
C3: compaction by loading with the level of 498 kPa.

In order to apply vacuum; mini-silo lids were fitted with a water-filled gas-release valve, and the valves were closed by vacuum from vacuum pump (McEniry et al., 2007).

Chemical analysis

After 50 days, all mini-silos were opened for analysis. Dry matter (DM) was determined by oven drying at 103°C during 24 h (ASAE Standards, 1994). Standard methods were used for determining fat, (CF) (AOAC, No.983.23), ash (AOAC, 1990) and cellulose; (CC) (AOAC, 1990) content was carried out according to Weende analysis method, as described by Akyıldız (1984). The pH values of both fresh materials and silage materials were obtained using the methods reported by Chen et al., (1994). Total nitrogen (T) concentration was measured by a Kjeldhal procedure, and Crude protein (CP) concentration was calculated as N x 6.25 (Vadez, 1988; Stan, 2001). Neutral detergent fiber (NDF), detergent fiber (ADF) concentrations and acid detergent lignin (ADL) concentration were estimated according to Van Soest analysis method (Close and Menke, 1986). Concentration of ammoniac (NH_3), ammoniac-nitrogen (NH_3-N) and total nitrogen (NH_3-N/TN) were determined to evaluate silage quality (Brooking, 2002). Acetic acid (AA) and lactic acid (LA) (%) were calculated according to spectrophometric method (Koc and Coskuntuna, 2003). Water-soluble carbohydrates (WSC) were determined with spectrophotometer (Anonymous, 1986). The volume of the mini-silo occupied by the silage was calculated using the measurement of the final settled depth of silage in the silo (McEniry et al., 2007). The percentage of compaction rate was calculated by dividing pore volume after compaction by whole mini-silo volume (Roy, 2001). Fleig point was calculated as described by Kılıç (1986).

An experiment was organized in a 2-year x 3-stage (BA, ML, BL) x 5 compaction (N, WV, C1, C2 and C3) x 4 (replication) factorial arrangement of treatments to elucidate the relative effects of these factors on the fermentation characteristics of ensiled sunflower.

Statistical analysis

Statistical analyze was done by using MSTAT computer program.

RESULTS AND DISCUSSION

Only the main effects of the stages of maturity on fermentation characteristics of sunflower silage were significant ($p < 0.05$), and these are presented in Table 1. pH values were lowest at the BA stages (3.8) and highest at the BL (5.37) stages. Peterson (1988) and Demirel (2006) stated

Table 1. Effects of the stages of maturity in silages and levels of significance of factors.

Maturity %	BA	ML	BL	LSD	CV
PH	3.8c	5.3b	5.37a	1.634	0.48
DM	18.47c	27.24b	33.98a	3.268	0.22
CP	10.586c	8.521b	8.882a	7.66	1.58
CF	1.678b	7.520a	7.504a	7.124	2.49
NH3-N0.827c	2.521b	2.630a	0.046	4.55	
NH3-N/TN	50.95 c	185.016a	175.70b	1.059	1.49
NDF	39.82c	44.718b	45.44a	0.189	0.85
ADF	35.82c	40.33b	40.93a	0.209	1.04
ADL	15.95c	16.62b	16.99a	0.250	2.93
CC	20.633c	27.827b	28.10a	0.146	1.11
WSC	5.737c	5.91b	7.417a	1.634	0.41
LA	1.771a	1.036b	1.002c	1.634	2.43
AA	0.420c	0.634b	0.673a	6.778	2.53
Flieg point*	89.94 **Ex**	47.48 **F**	58.16 **F**		

significantly at $p<0.05$.
*0-20, (**B**) bad; 21-40, (**M**) medium;41-60, (**F**) fair;61-80,(**G**) good; 81-100 (**Ex**) excellent (Flieg Point).

that a good quality silage pH should be under 4.3. The DM content was also increased in the silages with maturity. Bal (2006) and Toruk et al. (2009) also found that DM content increased as maturity increased. CP level at BA stage was higher than that at ML stage and BL stages. Similar results were found by Stan (2001); Putnam et al. (1990) and Bal (2006). CP content of sunflower decreased after the flowering stage, whereas concentration of ammonia-nitrogen (NH_3-N) increased. The concentration of NH_3-N content was the lowest 0.827 g kg^{-1} at BA, yet it increased at ML and BL stages. NH_3-N, g kg^{-1} content was good at BA, but was higher than required at ML and BL. In their study, Polat et al. (2006) attributed the high value of NH3-N to high pH values. Like NH_3-N, CF and NH_3-N/TN values were low at the early stage (BA). NH_3-N increased as sunflowers matured. NH_3-N should be under 80 g kg^{-1} TN according to Peterson (1988). The value of BA was found to be 50.95 g kg^{-1} TN, which is only below 80 g kg^{-1} TN in the treatments.

Silages at BA stage were excellent in quality based on fleig point but were not at ML and BL stages. Kılıç (1986) reported a positive relationship between fleig point and silage quality. Concentrations of NDF, ADF, CC, AA and WSC in whole sunflower-plant silage increased as maturity proceeded from BA stage to ML stage. Filya (2004) also found that WSC values increased with maturity. The levels of ADL were lowest at the ML stage and highest at the BA stage. Values of NDF, ADF, ADL and CC which were measured as 42, 39, 12 and 27 respectively by NRC (1989) were close values in this experiment. LA concentration, which was the primary organic acid, changed with maturity. The lactic acid concentration was higher for BA stage than for ML and BL stages. A similar trend was also observed and shown by Filya (2004).

Alçiçek and Özkan (1997) stated that the value of LA should be over 2.0% and the value of AA should be below 0.8% in quality silage. The values of this experiment about LA were not sufficient. The values of AA at all stages were found below 0.8%. The effects of the compaction levels on silage characteristics were shown in Table 2.

Values of pH were lowest at the C3 and highest at the NC treatments. The values were found higher than the value (4.3) mentioned by Peterson (1988). The DM content increased in the silages with compaction, whereas the contents of pH decreased. CP was similar to that of (WN and NC), (C1 and C2), and the CP content was the highest at C3 with 9.97. CF was low at the early stage (BA) and increased with maturing sunflower and compaction treatments. NH_3-N contents were the lowest at C3, intermediate at WN and C1, and the highest at NC. The highest NH3-N/TN was found at WN, and the lowest NH_3-N/TN at C2. NDF, ADF, CC, AA and WSC contents of silages decreased at compaction treatments (C1, C2 and C3), whereas the contents of ADL increased.

AA values were good for compaction treatments and the stages of maturity. In all the compaction applications, these values were found to be comparable to those found by Alçiçek and Özkan (1997). All values of LA were found lower than desired level (2.0%) (Alcicek and Ozkan, 1997). Nevertheless, depending on the compaction level, LA positively increased. Water-soluble carbohydrates (WSC) content was the highest at NC. McDonald et al. (1991) also found that WSC values decreased with maturity. WSC values changed with increasing compaction levels. Depending on compaction levels, a steady increase in Flieg values were observed, and the worst silage quality was determined during the NC application.

Table 2. Effects of compaction in silages and levels of significance of factors.

Compaction	NC	WN	C1	C2	C3	LSD
PH	4.93a	4.86b	4.81c	4.77d	4.73e	2.109
DM	25.32e	26.17d	26.78c	26.95b	27.59a	4.219
CP	9.177c	9.113c	9.298b	9.327b	9.973a	9.896
CF	5.203d	5.910a	6.00a	5.313c	5.410b	0.091
NH3-N	2.142a	2.072b	2.128ab	1.848c	1.773d	5.96
NH3-N/TN	141.77c	150.87a	126.68d	121.17e	145.62b	1.367
NDF	43.178b	44.490a	42.982bc	42.835c	43.158b	0.244
ADF	39.142b	40.905a	38.502c	38.722c	37.878d	0.271
ADL	15.612c	17.142ab	15.870c	16.748b	17.237a	0.322
CC	26.27a	26.36a	24.80c	25.40b	24.75c	0.188
WSC	8.415a	6.563c	7.033b	5.065d	4.697e	2.109
LA	1.122d	1.097e	1.243c	1.585a	1.302b	2.109
AA	0.788a	0.583c	0.642b	0.450d	0.415e	8.750
Flieg point*	58.44 **F**	62.94 **G**	66.16 **G**	68.1 **G**	70.98 **G**	

significantly at $p < 0.05$.
*0-20, (**B**) bad; 21-40, (**M**) medium;41-60, (**F**) fair;61-80, (**G**) good; 81-100 (**Ex**) excellent (Flieg Point).

Whole crop sunflower can be used to ensile, but the ensiling and nutritional quality depend upon the stage of maturity at the time of harvest (Tan and Tumer, 1996; Garcia, 2002b; Toruk, 2003; Toruk et al. 2009) and also here.

Interactions of year x stage; stage x compaction treatment; year x stage x compaction were found significant.

Conclusions

Fermentation characteristics of the sunflower silage were positively affected with maturity and increasing compaction levels.

Ensiling sunflower is more desirable at the stage of second harvesting time (ML). But, increasing fiber content can be a problem during chopping. This is also a cause of less nutrition value.

Finally, optimum sunflower for silage was found to be the best when harvesting at the stage of one-third milkline (ML) and compaction with the level 498 kPa (C3).

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