Journal of Animal and Veterinary Advances 8 (9): 1873-1877, 2009
ISSN: 1680-5593

Dsensity, Porosity and Permeability Rates of Sunflower Silage Under Different Compaction Conditions

[1]F. Toruk, [1]E. Gonulol, [1]P. Ulger and [2]H. Kocabiyik
[1]Department of Farm Machinery,
Faculty of Agriculture, Namik Kemal University, 59030 Tekirdag, Turkey
[2]Department of Farm Machinery,
Faculty of Agriculture, Canakkale Onsekizmart University, 01130 Canakkale, Turkey

Abstract: In this study, the determination of density, porosity and permeability rates of sunflower silage at different stages of maturity and under different conditions of compaction was aimed. Whole-plant sunflower (*Helianthus annuus* L.) was harvested at three different maturity stages; (BA, Beginning of Anthesis (78%), ML, one-third Milk Line (70%) and BL, Black Line (64%)). Five compaction levels were done during ensiling. These were control (no compaction), vacuum and compaction with 150 kPa (C_1), 248 kPa (C_2) and 498 kPa (C_3). The chopped forages were ensiled in PVC (5.7 L) mini-silos. For porosity measurements, a tube system was designed, which operated according to ideal gas law. Permeability was measured to be the time during, which 1 L water passed through the silo container. The results of this study showed that the values of porosity, permeability and density were found to be significantly affected by the applications of compaction and stages of maturity.

Key words: Density, porosity, permeability, sunflower silage, compaction level

INTRODUCTION

Porosity value is one of the significant factors that are used for well-quality ensilage. How well a crop is preserved by ensiling depends on minimizing exposure to oxygen during storage and feed out (Muck and Holmes, 2003). While, the quality of the seal is the key factor in influencing oxygen exposure during storage, the porosity of the silage is the principal factor affecting oxygen movement into the feed-out phase of the silo once the silo is opened for emptying. If a silo is not covered or the seal is substantially damaged, the rate of spoilage losses during storage will be affected primarily by silage porosity as well. Porosity is a function of the density and moisture content of the crop (Pitt, 1986). Consequently, in horizontal bunker or drive-over pile silos the packing practices during filling are important in determining the density and porosity of the silage and the silage's subsequent susceptibility to spoilage losses during storage and feed out (Muck *et al*., 2004).

Pressure had a significant impact on increasing the density of corn. Density is an important factor in the final quality of silage (Roy *et al*., 2001). High density will result in a low porosity and therefore, reduce air infiltration in an imperfectly sealed silo (Rees *et al*., 1983). A high silage density is desirable to increase storage capacity and to reduce porosity, thereby reducing oxidation loss and preserving a high feed value. However, obtaining a high silage density can be expensive because of requirements for heavy compaction equipment, prolonged compaction time, suitable layer placement and thickness (Savoie *et al*., 2003).

The permeability of silage is of great significance in aerobic deterioration. It is theoretically related to porosity (Williams, 1994). Permeability of alfalfa hay decreased with increasing moisture levels and pile depth (Ahn *et al*., 2007).

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

The objective of this study was to estimate the effects of the density, porosity and permeability rates of sunflower silage under three maturity stages and five compaction levels.

MATERIALS AND METHODS

Sunflower (*Helianthus annuus* L.) used in this experiment was sowed in April, 2006 during the summer

---

Corresponding Author: Fulya Toruk, Department of Farm Machinery, Faculty of Agriculture, Namik Kemal University, 59030, Tekirdag, Turkey

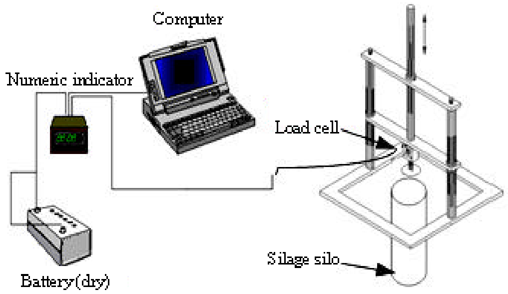

Fig. 1: Trial set for compaction and load measure

growing season. The variety of sunflower used in this experiment was Meric F1. The experiment field consists of two plots used for wheat and sunflower rotation for several years. Seeding rate was 140,000 seeds ha^{-1} with 70 cm row width and 8 cm with planting depth. Sunflower was harvested at three different maturity stages. These were the Beginning of Anthesis (BA), one-third Milk Line (ML) and Black Line (BL).

A conventional silage machine with a single row was used for harvesting. The average particle length of chopped sunflower was 11 cm. The chopped forages were ensiled in PVC (5.7 L) mini-silos (Peterson, 1988).

The chopped material was filled with compaction and vacuum mechanisms. Trial set for compaction is shown in Fig. 1.

The set has mainly four units. These are battery, numeric indicator, for converting signals (come from load cell) to numeric value, computer, for recording numeric values (coming from the numeric indicator) and load cell, for converting force to signal. ESIT, TCS 500 model load cell was employed by means of the shear box method. A laptop computer and ProComm software were used to evaluate the numerical values.

Sunflower was ensiled with the following vacuum and compaction methods.

NC (control) = Without vacuum application and without compaction
WV = Vacuum application and without compaction
C_1 = Compaction by loading with the level of 150 kPa
C_2 = Compaction by loading with the level of 248 kPa
C_3 = Compaction by loading with the level of 498 kPa

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).

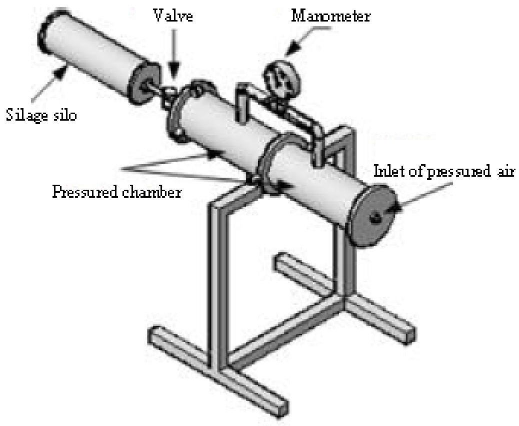

Fig. 2: Porosity measurement apparatus (Kocabiyik *et al*., 2004)

After 50 days, all mini-silos were opened for determining density, porosity and permeability rates.

Determination of density: Density was determined by the following Eq. 1:

$$\rho = m/v \qquad (1)$$

where:

ρ = The density ($g\ mL^{-1}$)
m = The mass (g)
v = The volume (mL)

Determination of porosity rate: Porosity, pore space can be filled with fluids including gas or water in silage (Mohsenin, 1980). Porosity was measured with a special apparatus, which was designed by Kocabiyik *et al*. (2004). Porosity measurement apparatus was shown schematically in Fig. 2.

This apparatus consisted of two steel chambers with the same volume. These chambers had the same axis and were separated by a divider to prevent volume contact. The connection of the two chambers was done by welding. One of the chambers was connected to the silage silo by a valve. A manometer and a valve were added to the apparatus to control pressured air between the chambers and to determine the air pressure value (Kocabiyik *et al*., 2004).

For the measurement of porosity, first, chamber of the measurement apparatus was filled with pressured air. Desired air pressure was adjusted by a manometer and a valve, which was located at the pressure air inlet. After chopped materials were filled into experimental silo, the lid of the mini silo was closed leak proof. Then the valve between the chambers and the mini silo was opened and the filling of air in pressured air chambers to the voids among the silage in the mini silo was supplied. Decrease in pressure of the pressured air that filled the voids among the silage in mini silo was obtained by reading the manometer. Then porosity values according to ideal gas law were calculated using the pressure values obtained (Kocabiyik *et al*., 2004). According to ideal gas law:

$$P_1V_1 = MR_1T_1 \qquad (2)$$

$$R_1T_1 = R_2T_2 = RT \qquad (3)$$

where:

P_1 = The absolute pressure
V_1 = The volume of pressured air chamber
M = Air mass
R_1 = Gas constant of air
T_1 = Absolute temperature

Index of 2 for the same values represents values in mini silo. Total air Mass in apparatus (M) is air mass in pressured air chamber (M_1) and air mass in mini silo (M_2).

$$M = M_1 + M_2 \qquad (4)$$

$$((P_1V_1)/RT) = (((P_2V_1)/RT)+(P_2V_2)/RT)) \qquad (5)$$

$$(V_2/V_1) = ((P_1\text{-}P_2)/P_2) = € \qquad (6)$$

As shown in Eq. 6, porosity ratio (€) is the rate of volume in mini silo to the volume in pressured air chamber. In tests, first measured pressure value was fixed at 1.3 kg cm^{-2}.

Determination of permeability: Permeability was determined by means of passing 1 L water into the ensiled material in the mini silos. Permeability was measured by reading the time period of the water that was drained from the silo. Permeability was calculated according to Darcy law as follows:

$$Q = -KA(\Delta h/L) \qquad (7)$$

$$K = QL/A(-\Delta h) \qquad (8)$$

where:

Q = Water flow rate (cm^3 min^{-1})
A = Square (cm^2)
L = Length of the silo
Δh = Height of water
K = Permeability (cm min^{-1})

The experiment was organized in a 3 (stages of maturity; BA (beginning of Anthesis), ML (one-third Milkline), BL (Blackline) × 5 (compaction treatments; NC, WV, C_1, C_2 and C_3) factorial arrangement of treatment. Each treatment combination was replicated 4 times. Data was evaluated by MSTAT statistics program.

RESULTS AND DISCUSSION

Density: The densities of the sunflower silages harvested at the three maturity stages and under five different ensile applications (without compaction, vacuum and three compaction levels) were given shown in Fig. 3.

The differences among maturity stages and ensile applications in density were found to be significant (F** = 3.92 for maturity stages and F** = 14.32 for ensile applications). Muck *et al*. (2004) found that density was affected by pressure and moisture content, but not by time of compaction. The density of the samples ranged from 572-1085 kg m^{-3}. The highest densities observed at the BL stage and under C_3 application, the lowest densities at the BA stage and under NC application. Similar results were also found by Roy *et al*. (2001). They stated that pressure had a significant effect in increasing the density and moisture. In the highest densities found low porosity values as shown by Rees *et al*. (1983) and Savoie *et al*. (2003).

Porosity: Porosity of the sunflower silages investigated at the three maturity stage levels and five different ensile applications were shown in Fig. 4. Changing porosity according to maturity stages and ensile applications were found to be statistically significant (F** = 32.34 for maturity stages and F** = 100.23 for ensile applications).

The porosity value of the silages was increased at maturity stage, but decreased with increasing compaction values. The highest porosity value (57%) was at the BL stage and under NC application. This was supported by the results of Williams (1994), who found low moisture content results in a higher porosity of the conserved forage. The lowest porosity value (15%) was at the BA stage and under C_3 application. Peterson (1988) studied on corn ensiling and found that porosity values as from 43-38% according to maturity.

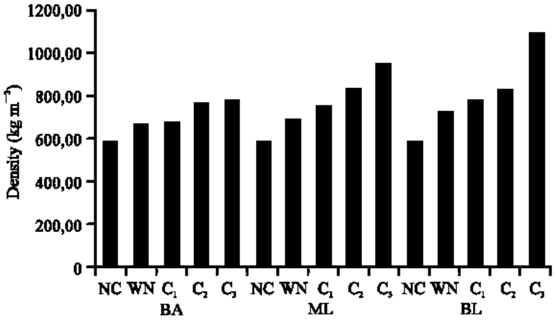

Fig. 3: Density of sunflower silages at three maturity stages and five different ensile applications

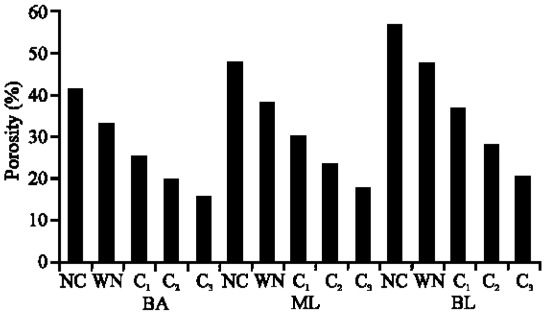

Fig. 4: Porosity of the sunflower silages at the three maturity stages and under five different ensile applications

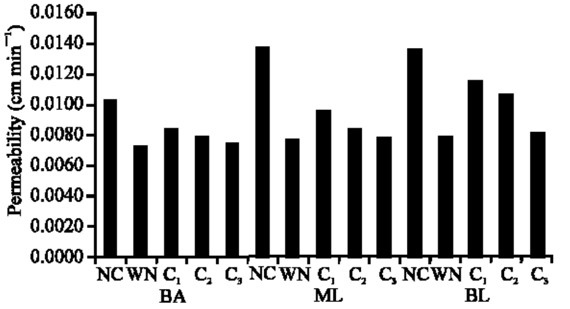

Fig. 5: Permeability of the sunflower silages at the three maturity stages and under five different ensile applications

Like this study, Roy *et al.* (2001) explained that the low porosity could be achieved by increasing compacting.

Permeability: The permeability of the sunflower silages harvested at the three maturity stages and five different ensile applications were shown in Fig. 5. Permeability showed significant variations at maturity stages (F** = 7.63) and under ensile applications (F** = 14.95). The highest permeability (0.0488 cm min^{-1}) was observed at the BL stage and under NC application. The lowest permeability (0.0072 cm min^{-1}) was observed at the BA stage and under WN application. Montross and McNeill (2005) found that the permeability value of the silages showed variation according to moisture content (maturity stage), which was similar to that of this study.

Correlation between density, porosity and permeability of the sunflower silage investigated at the three maturity stage levels and under five different ensile applications were shown in Table 1. The correlation between density and permeability was not found to be important, whereas the figure was significantly important between the density and porosity (0.707**). It can be explained that pore inside silage was diminished by applying compaction. Holmes and Muck (2007) also determined porosity is most influenced by density. Permeability increased with increasing porosity and decreasing density, but the relationship between permeability and moisture content is complex as mentioned by Williams (1994). There was significant linear correlation between permeability and porosity (0.665**), since, pore helped water pass quickly inside silage.

Table 1: Correlation of density, porosity and permeability of sunflower silage

Variables	Density (kg m^{-3})	Permeability (cm min^{-1})
Permeability (cm min^{-1})	-0.443^{NS}	-
Porosity (%)	-0.707**	0.665**

**Significant at $p<0.05$, NS: Not Significant

CONCLUSION

The results of this study revealed that maturity stages and ensile applications had important effects on the density, porosity and permeability values. The density of sunflower silage was influenced by maturity stages and ensile applications. At the stage of the maturity, the densities changed, due to the higher DM concentrations plants matured. The porosity values of the sunflower silage increased at different maturity stages, but decreased with increasing compaction values. Permeability decreased when compaction levels were increased. The higher permeability values were observed at the lowest moisture content. Whole crop sunflower can be used to ensile, but the ensiling and nutritional quality depends upon the stage of maturity at the time of harvest. The relationship between permeability and porosity highly significant.

ACKNOWLEDGEMENT

This study was supported by Turkya University scientific research project fund under the project number TUBAP 587.

REFERENCES

Ahn, H.K., T.L. Richard and T.D. Glanville, 2007. Laboratory determination of compost physical parameters for modeling of airflow characteristics. Int. J. Integrated Waste Manage., 28: 660-670. DOI: 10.1016/j.wasman.

Garcia, A., 2002. Alternative forages for dairy cattle: Soybeans and sunflowers. Dairy Sci., pp: 1-2.

Holmes, B.J. and R.E. Muck, 2007. Packing Bunkers and Piles to Maximize Forage Preservation. ASABE 6th International Dairy Housing Conference Proceeding, June 16-18. PMID: 701P0507e.

Kocabiyik, H., T. Aktas and B. Kayisoglu, 2004. Porosity Rate of Some Kernel Crops. J. Agron., 3 (2): 76-80. PMID: 20043135514.

McEniry, J., P. O'kiely, N.J.W. Clipson, P.D. Forristal and E.M. Doyle, 2007. The relative impacts of wilting, chopping, compaction and air infiltration on the conservation characteristics of ensiled grass. Grass Forage Sci., 62: 470-484. TEAGASC Blackwell Publishing Ltd. DOI: 10.1111/j.1365-2494.2007.00602x.

Mohsenin, N.N., 1980. Physical properties of plant and animal materials. Gordon and Breach, Science Publisher, Publisher: Routledge, Inc. one Park Avenue New York, pp: 105.

Montross, M.D. and S.G. McNeill, 2005. Permeability of corn, soybeans and soft red and white winter wheat as affected by bulk density. Applied Eng. Agric. USA, 21 (3): 479-484. IDs No.: 934NR.

Muck, R.E. and B.J. Holmes, 2003. Bag silo densities and losses. Transactions of the ASABE, 49 (5): 1277-1284. USA. IDS No.: 106YS.

Muck, R.E., P. Savoie and B.J. Holmes, 2004. Laboratory assessment of bunker silo density. Part I:Alfalfa and grass. Applied Eng. Agric., 20 (2): 157-164. USA IDs No.: 810UT.

Pitt, R.E., 1986. Dry matter losses due to oxygen infiltration into silos. J. Agric. Eng. Res., 35: 193-205. IDs No.: E8444.

Peterson, K., 1988. Ensiling of forages: Factors affecting silage fermentation and quality. Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management, Uppala, Report No.:179, pp: 46.

Rees, D.V., H.E. Audsley and M.A. Neal, 1983. Some physical properties that affect the rate of diffusion of oxygen into silos. J. Agric. Sci., 100 (3): 601-605. DOI: 10.1017/S0021859600035358.

Roy, M.B., Y. Treblay, P. Pomerleau and P. Savoie, 2001. Compaction and density of forage in bunker silos. ASAE Annual International Meeting, Paper No.: 01-1089.

Savoie, P.K., K.J. Shinners and B.N. Binversie, 2003. Hydrodynamic separation of grain and stover components in corn silage. Applied Biochem. Biotech., 113: 41-54. IDs No.: 817OG.

Tan, A.S. and S. Tumer, 1996. Research on the evaluation of silage quality of sunflower. J. Aegean Agric. Res. Institute. Menemen Izmir, Turkey, 6: 45-57. http://www.aari.gov.tr/anadolu/ozet-ABS-96-1.htm.,

Toruk, F., 2003. Sunflower silage and mechanization. J. TürKoop Ekin, Published by IMAJ Ic ve Dis Tic. Turkey, pp: 80-83. AS Number:14/4 www.tarimkredi.org.tr/ekin.Ankara.

Williams, A.G., 1994. The permeability and porosity of grass silage as affected by dry matter. J. Agric. Eng. Res., 59 (2): 133-140. IDs No.: PQ165.