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88

Effects of compaction pressure on the temperature distribution in bunker type silage silo

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ABSTRACT

The aim of the research has been to determine effects of compaction pressureon temperature distribution in the silage material in bunker silo.The pressure measurement systemdeveloped within the scope of this research was used to measure the pressure distribution in the silo. Hobo E-348-UA-002–08 model temperature sensors were also used for temperature measurements.The all sensors were positioned in the silo at predetermined points. Temperature and pressure values were recorded in a datalogger during ensiling, fermentation and after fermentation stages.The data collection system is based on a graphical programming language NI LabVIEW software and NI CompactDAQ hardware modules.Work machine having palette of which weight was 13700 kg has been used to compact of maize silage.The average temperature of silage in the silo was 23.35 °C during ensiling, 29.04 °C during fermentation and 23.45 °Cduring the after fermentation stage.The maximum pressure on the silage material was applied during storage with a mean value of 0.34 bar. The highest temperature and pressure wereon the line in thefront of the silo while the lowest temperature and pressure were in the close to the rear wall of the silo.The effect of compaction pressure applied during the ensiling stage also continued during the fermentation stage.It was determined that there is a relationship between the pressure applied to silage and temperature. Results showed that temperature in the silage has been increased with increasing compaction pressure.

Key words: Silage, CompactionPressure, Temperature, Bunker silo.

Compaction is an important criterion for measuring the quality of silage. In order to obtain a quality silage, it is necessary to increase the density and to remove oxygen from inside the silage as much as possible. For this, the silage must be compactedeffectively.

Density and quality of silage are influenced by pressure, moisture, compacting vehicle mass and layer thickness (Roy *et al*. 2001). Muck and Holmes (2000) observed that density of silage is variable in bunker silos. Higher density in silage is important for silage quality and preservationfor longer period of time. More dry matter is stored in the same volume and costs of storage are reduced.Savoie*et al*. (2004) found that the density of silage was affected by layer thickness and pressure but not by time of compaction under laboratory condition. Latsch (2014) indicated that one main problem in compacting work of silage in bunker silos seems to be the heterogeneity of bulk density. This problem occurs, when forage is not well distributed after unloading and peaks and troughs of grass lie directly side by side.

Borreani and Tabacco (2010) reported that quality of silage is related to the temperature of silage mass in the bunker silo.Temperature is an important factor affecting silage stability, silage quality and protein damage during the entire storage period (Jiang *et al*. 1987).

Previous studies have generally examined the relationship between compaction and density. There are no studies to determine the pressure acting on the material. Most of the work is done in laboratory conditions. In this study, the relationship between temperature and compression pressure was determined in silo and site conditions.

MATERIALS AND METHODS

Maize fodder was harvested at 27% dry matter by a forage harvesting machine (CLASS 940).The chopped material were ensiled in bunker silo.The measurement sensors were located inside silo at predetermined points during filling.A single compaction equipment was used for compaction. Temperature and pressure values were recorded in a datalogger during ensiling, fermentation and after fermentation stages.

Compaction equipment

The CAT 955 L type work machine having palette of which weight was 13700 kg has been used to compact the

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silage material.The palette has a width of track shoe 0.43 m and a length of track on ground 2.35 m and ground contact area of palette was 2.03 m^2.

Bunker silo and measurement points

Bunker silodimensions are 7500 mm x 27000 mm x 2250mm. Figure 1 illustrates the 24 measurement points in bunker silos. Pressure and temperature measurement sensors were installed at these measuring points.

Three measurement lines were identified along the silo infront of the silo (C), in the centre (B) and behind it(A). Three points defined on each line (1.0 m from both the right (R) and left (L) side walls and in the middle (C) of the silo) and three heights (0,5 m, 1 m and 1,5 m from the floor.Temperature sensors were only located on the 1 m height from the floor layer.

bar pressure. In this hydraulically operated system, water was used for pressure transmission (Turner andRaper, 2001).

The measurement and storage unit of the PMS was placed in a central position of the side surface of the silo.

Data collection and storage

The data collection system is based on a graphical programming language NI LabVIEW software and NI CompactDAQ hardware modules. Data is collected by using two NI 9208 24-bit analog input modules in a NI cDAQ-9184 chassis. The NI 9208 current input module has 16 channels of ±21.5 mA input, high resolution mode with 50/ 60 Hz rejection for noise rejection. Data acquisition system measures 16 current channels at 500 S/s with 24-bit resolution and sends data to a portable computer over USB.

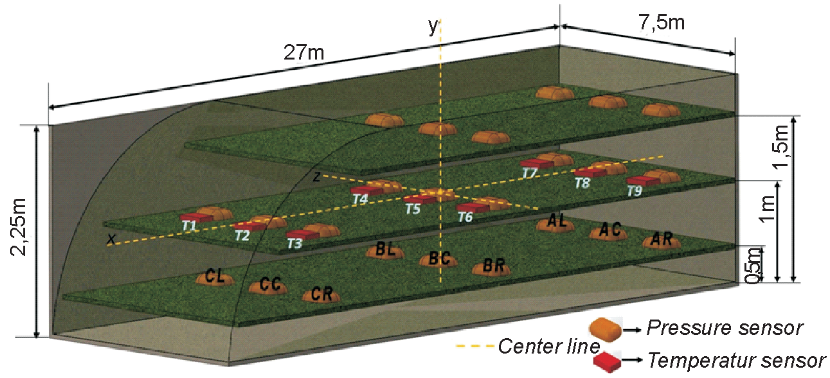

Fig. 1. Measurement points in the bunker silos

Pressure measurement system (PMS)

PMS has mainly five units (Fig. 2). These are pressure sensing rubber globe (PRG), hydraulic hose connection (HHC), pressure sensors (PS), data collection, recording and storage (DRS) and portable computer (PC).

PRGwas connected to pressure sensors via the hydraulic hoses. The sensor outputs were connected to NI DAQ measurement and storage system. Mesens 500 series 4–20 mA of the 4 bar capacity pressure sensors were used. The total pressures generated on the globes were transmitted to the sensors regardless of direction. The connection hoses were chosen in a construction withstand a maximum of 10

This data is stored in a MS Excel file on the computer by using a user interface created with NI Labview software.

Calibration

To determine whether the output values of pressure sensors used in the measurement system especially under dynamic conditions are correct and reliable values or not two different calibration curves were created(Dalmýs, 2006; Akýncý, 1994). Repeated measurement experiments were carried out to determine the deviations in the measured values at repeated loads (Dalmýs, 2006; Akýncý, 1994). Load values in the experiments were selected by taking the

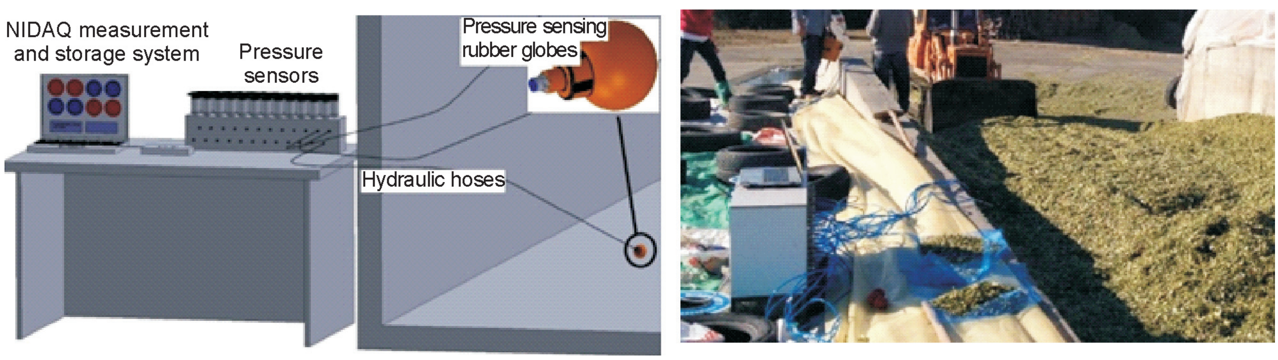

Fig. 2. Pressure measurement system (PMS)

possible loads encountered in the field conditions and sensor capacities into account.

Temperature

Hobo E-348-UA-002-08 model temperature sensors were used for temperature measurements.
Effects on temperature of the pressure was assessed in three categories.

1. Ensiling (ET)
2. Fermentation (FT)
3. After fermentation (AFT)

Statistical analysis

To evaluate statistical significance between the pressure and temperature in bunker silo, the data were analyzed using the ANOVA procedure and significant differences among means were determined by Tukey and LSD multiple rangetest.

RESULT AND DISCUSSION

Temperature and pressure changes during the ensiling

The effects of compaction pressure on temperature has been found significant in regionswhile not found significant as statistically in position. Measured values of temperature and pressure during the ensiling are given in Table 2 and

The lowest temperature has been measuredin the A region (18.30°C), the highest temperature has been measured in the C region (29.26°C). Pressure also was the lowest in the A region (0.29 bar) and the highest inthe C region (0.38 bar). Temperature difference among locations has not been found different. The lowest temperatureand pressurehave been at the left side walls.

Toruk *et al*. (2010) were reported that fermentation characteristics of the silage were affected positive with increasing compaction.The pressure in theright side walls was higher than the pressure in the middle of the silo andin the left side walls.D'Amours and Savoie (2004) found that

Table 2. Temperature and pressure values measured during the ensiling

Region	Temperature°C	Pressurebar	Position	Temperature°C	Pressurebar
A	18.30±1.44[a]	0.29±0.08[a]	Left	23.09±5.52	0.282±0.16
B	22.47±4.03[b]	0.35±0.12[ab]	Center	23.76±5.51	0.340±0.09
C	29.26± 4.04[c]	0.38±0.09[b]	Right	23.19±5.87	0.373±0.11
Av.	23.35±5.62	0.34±0.10	Av.	23.35±5.42	0.313±0.12
P	<0.05	<0.05		>0.05	>0.05
F	30.838	3.401		0.037	2.150

* Mean values on the same column with the same superscript do not differ significantly at p<0.05

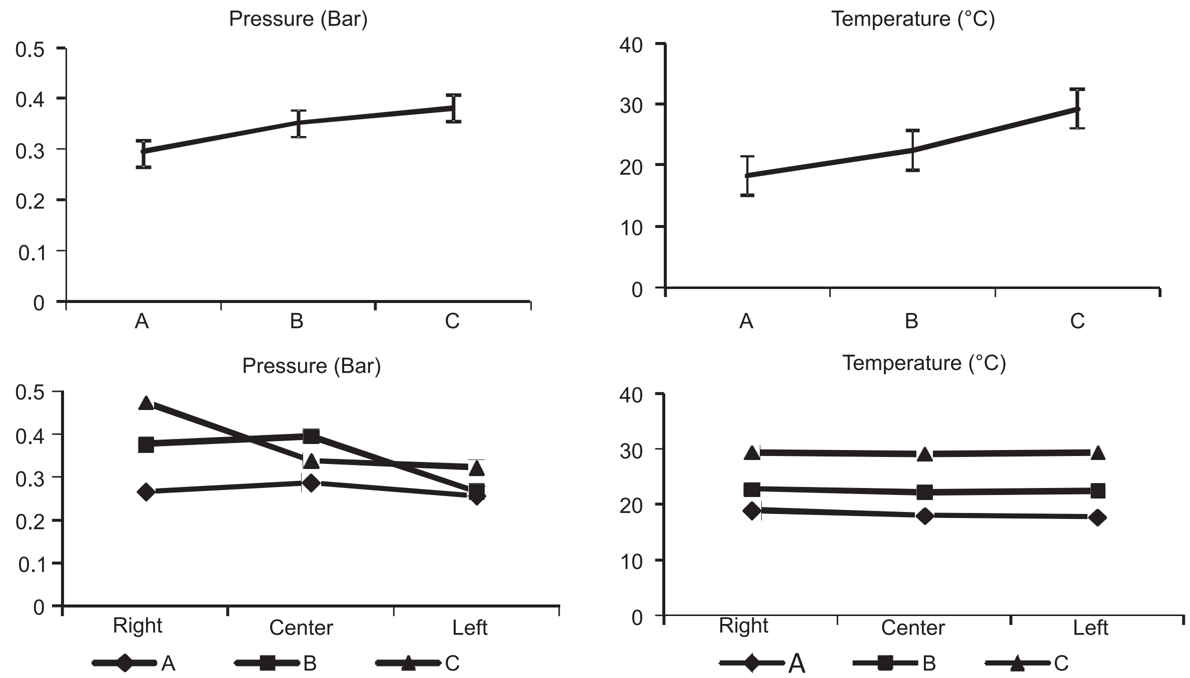

Fig 3.Temperature was increased with increasing pressure.

Table 3. Temperature and pressure values measured during the fermentation

Region	Temperature°C	Pressurebar	Position	Temperature°C	Pressurebar
A	25.12±1.46 [a]	0.022±0.011 [a]	Left	29.03±3.6	0.026±0.01
B	27.74 ±0.67[b]	0.042±0.036[b]	Center	28.80±4.0	0.036±0.01
C	34.26 ±0.47[c]	0.044±0.020 [b]	Right	29.29±4.5	0.045±0.06
Av.	29.04±4.03	0.034±0.022	Av.	29.04±4.05	0.022±0.03
P	<0.05	<0.05		>0.05	>0.05
F	315.84	4.84		0.043	2.662

*Mean values on the same column with the same superscript do not differ significantly at p<0.05

the density in the centre was higher than the density near the wall at the bunker silo.At some locations there was more density in the near the wall.This indicates that the operator spent more time on regions near the wall than the other regions.Similar values have been found inthis research.Latsch (2014) also found that the compacting time in the right side walls is in every case a bit longer than in the left side walls. This fact can be explained with the individual influence of the tractor or work machine driver.

Temperature and pressure changes during the fermentation

Measured values of temperature and pressure during the fermentationwere given in Table 3. Temperature during the fermentation stagehas been measured higher than the ensiling stage.

The temperature and pressure differences among the regions at the fermentation stage have been found different. The lowest temperature values have been found in A region with 25.12°C and the highest in C region with 34.26°C. Pressure also has been the lowest in the A region and highest in the C region. The pressure measured during the fermentation stage is the pressure measured on the material without compression effect.Pressure and temperature among locations have not been found significant.

The pressure values measured during the fermentation stage were significantly lower than the pressure values measured during the compression stage.Pressure also were the lowest inthe A region with 0.022 bar and the highest in the C region with 0.044 bar. The highest pressure was in the in the right side walls.

The temperature values in the bunker silo were quite variable. The results are presented in Figure4.The maximum temperature recorded was 35.95°C in the C region on fermentation stage and then temperature was gradually decreasing to 32°C at the end of fermentation stage. Measured values of temperature and pressure during the fermentation are given in Figure 5.

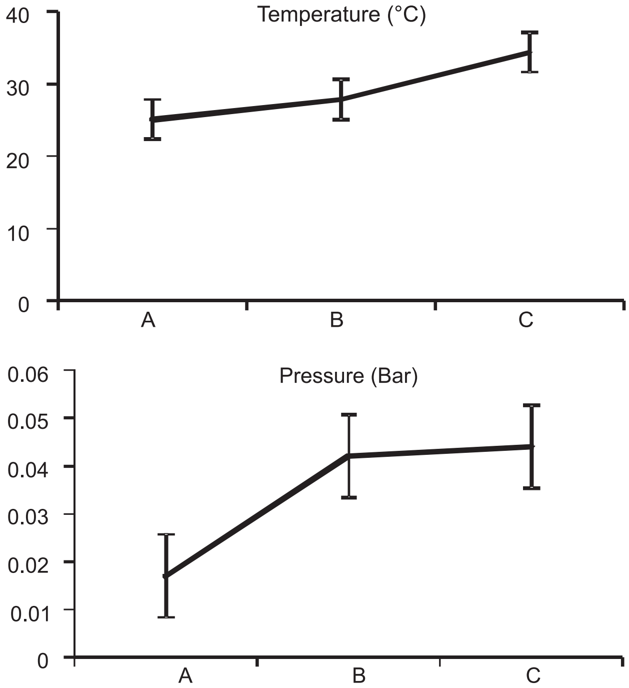

Fig. 5. Temperature and pressure changesduring the fermentation

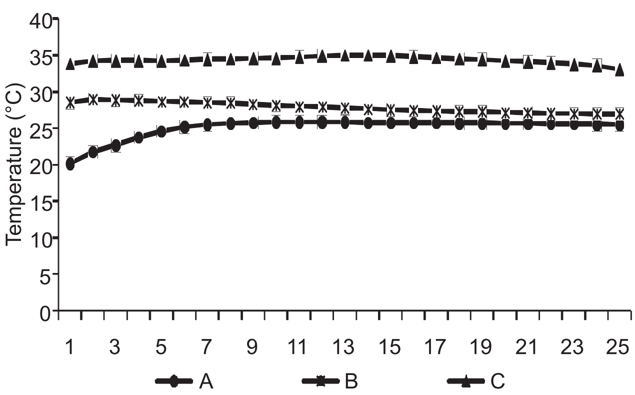

Fig. 4. Temperature changes during the fermentation

High temperatures above 115–120°F (46–48°C) can lead to heat damaged protein. Temperatures in this range may also be detrimental to many lactic acid bacteria that are needed to achieve a successful fermentation (Kung, 2011; Jiang *et al*. 1987). The temperatures in this study were found almost successful fermentation temperatures. This is also shown that temperature of the silage in bunker was positively affected with increasing compaction force.

Temperature and pressure changes the after fermentation

Temperature values measured after the fermentation are given in Table 4. The effects of compaction pressure on temperature have been found significant in regionswhile not found significant in position. The pressure values were

Table 4. Temperature and pressure values measured after the fermentation

Region	Temperature °C	Pressure bar	Position	Temperature °C	Pressure bar
A	21.58±3.28[a]	-	Left	22.28±5.02	-
B	23.93±3.12[ab]	-	Center	24.36±4.14	-
C	25.10±6.12[b]	-	Right	23.98±4.44	-
Av.	23.54±4.57	-	Av.	23.54±4.57	-
P	<0.05			>0.05	
F	3.487			1.237	

*Mean values on the same column with the same superscript do not differ significantly at p<0.05

too small to be measured in the after fermentation period.

The temperature values remained 30°C for more than two months. Temperature sensors were retrieved on February 25. The temperature of silage corn after fermentation slowly declined to 21–24°C from 34.69°C. Similar values were found by Kung (2011). The lowest temperature values has been found in the A region with 21.58°C and the highest in the C region with 25.10°C. The lowest temperature measured were17–19°C when the fermentation was complete. The effect of the compaction pressure applied in the silage preparation continued during storage.

CONCLUSION

Results showed that temperature was increased by increasing compaction force.Temperature and pressure values were lowest at the A region and highest at the C region in bunker silos. This shows that there is less compaction on the area near the back wall of the silo. Different pressure values are measured in the silo.This indicates that the operator has not operated on the same working time on different regions of the surface of silage during compression.This shows that operator experience in making of silage is as important as other factors affecting silage quality.

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