ASSESSING THE COMPARATIVE PERFORMANCE OF PAINTED AND NON-PAINTED METALLIC GRAIN STORAGE FACILITIES ON MAIZE GRAIN

M.SC. (ENVIRONMENTAL SCIENCE) THESIS

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UNIVERSITY OF MALAWI

CHANCELLOR COLLEGE

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M.Sc. (Environmental Science) Thesis

By

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B.Sc. (Agriculture-Crop Science)-University of Malawi

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University of Malawi

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JUNE, 2012

DECLARATION

I the undersigned hereby declare that this thesis is my own original work which has not been submitted to any other institution for similar purposes. Where other people's work has been used acknowledgements have been made.

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Full Legal Name

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Signature

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Date:

CERTIFICATE OF APPROVAL

The undersigned certify that this thesis represents the student's own work and effort and has been submitted with our approval.

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DEDICATION

This thesis is dedicated to my husband Jupiter Simbeye and our daughter Luseshelo. In a special way I also dedicate this thesis to my parents, Rose and Watson Zgawa Luhanga, for the big role they played in my life.

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I would like to thank my supervisors, Dr. P. Kambewa, of Economics Department, Dr. M. Katundu, of Home Economics Department and Mrs. E. Chirwa, of the Mathematical Sciences Department Chancellor College, for their untiring guidance during the period of my study.

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ABSTRACT

Lack of effective storage facilities to mitigate post harvest losses threatens the profitability of harvested maize grains. In Malawi, small scale farmers use traditional cribs, gunny bags and pesticides which just aggravate the losses. Currently small metallic grain storage facilities, which have proven to be effective, have been introduced. The effect of these small metallic grain storage facilities on maize grain in the tropics has little been studied and documented. This study set out to investigate the effect of painting on the temperature and quality of maize in small grain metallic silos. Specifically the study set to investigate the effect of painting on the storage temperatures in small grain metallic silos; to investigate the level losses of grain stored in painted and non-painted metallic silos.

An experiment was conducted to assess the comparative performance of painted and non-painted metallic grain storage facilities on maize grain under a typical tropical weather condition in Zomba, Malawi. Four small grain metallic silos of 250 kg capacity were installed. Two were painted white, and the other not painted. Each silo was filled with 250 kg of MH 18 maize variety (Zea Mays) at 11.5 % moisture content (wet basis), obtained from Makoka Research Station. The cleaned, weighed and sound maize grains were stored in the silos, which were then tightly closed and placed under a shed. Temperature variations within and outside the silos were monitored for 120days during storage.

Results on temperature variation, moulding and caking between painted and non-painted metallic silos have been documented. Higher temperatures have been constantly observed in non-painted silos. This was true in all silo locations. These results were consistent when using graphs, t-test or ANOVA. Caking and moulding was also more pronounced in non-painted silos than painted ones. To a greater extent, this was more adverse on the silo walls.

The results of this study provide satisfactory evidence that painting had a considerable effect in controlling inside silo temperatures and also helped to maintain the quality of the stored grain. This clearly shows that painting can greatly improve the performance of the metallic silo and bring gains in the quality of the stored grain. In this regard, white painting of small metallic grain silos would be highly recommended to all stakeholders, particularly, small scale farmers in similar tropical conditions.

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LIST OF ABBREVIATIONS AND ACRONYMS

GTZ: Deutsche Gesell schaft fur International

HOBO: Name of thermometers used (HOBO data loggers)

ANOVA: Analysis of Variance

LSD: Least Significant Difference

FAO: Food and Agriculture Organisation

CHAPTER ONE: STATEMENT OF THE PROBLEM

1.1 Introduction

World storage of grain remains a vital part of the world economy. Grains are consumed directly by people, processed into other foods and fed to livestock. New developments or enhancements to the existing technologies in order to protect stored products, for small scale farmers is a powerful factor in reducing post harvest losses (Proctor, 1994). Post harvest losses can be due to the proliferation of storage insects, high moisture content of grains before storage, rodents, fungi multiplication due to excessive humidity in particular Aspergillus species and lastly weather influences in bulk storage which cause temperature changes (GTZ, 2006).

In Kenya, particularly Eastern Kenya, weevils and large grain borers have been singled out as the major causes of post harvest grain losses. Weevils account for 10-20 % post harvest losses whilst larger grain borer causes over 30 % of the losses, sometimes wiping out the entire harvests during severe infestations. This has been as a result of poor storage facilities which include substandard storage and pesticides which have aggravated the attack and losses. Traditional cribs and gunny bags (Figure 1 in Appendix) are the most common storage facilities used by the farmers in the area (Muhindi, 2008). In Tanzania, farmers were reported to have suffered up to 30 % losses from the larger grain borer, a destructive pest of stored maize due to the poor storage facilities used (Compton et al, 1992).

Uganda and Zambia experiences post harvest losses of about 17 % and 21% respectively. In Somalia post-harvest losses are estimated at 20-30 % of the production (GTZ, 2006).

In 2008, Malawi experienced post harvest maize grain losses of about 40% due to pests, weevils and poor storage facilities like traditional cribs and gunny bags, (Figure 1 and 2 in Appendix). Use of pesticides like Actellic, Super Guard Dust, Shumba super by farmers have just aggravated the attack (Malawi Government, 2008). Various attempts have also been made to mitigate this problem, like the introduction of a biological control of the larger grain borer *Prostephanus truncates*, (Figure 2 in Appendix) a pest of stored maize and other starch staples from meso-America using a predatory beetle *Teretrius nigrescens.*

As a way of addressing the problem of post harvest losses, the Malawi government is constructing storage facilities at national level, and with timely support from development partners, small metallic grain silos (see Figure 2 in Appendix) are being fabricated and constructed at village level with the aim of improving grain storage among the poor rural communities (Malawi Government, 2008). In the 2007/08 financial year alone, a total of 600 such storage facilities have been constructed and distributed to poor rural communities (Malawi Government, 2008). The fabricated metallic silos are of various sizes. This new technology is proving effective in protecting harvested grains from attack not only from these deadly weevils, but also from other insects and pests.

They are made in such a way that they are airtight, therefore minimizing oxygen and killing any weevils or pests that may be inside. They also completely lock out weevils and large grain borers or any insect or pest that may want to invade the grains inside. Metallic silos are not only guaranteeing full protection against the destructive pests, they are promising to be the ultimate weapon for improving food security for small-scale farmers.

However this being the case, these silos of temperate region origin, are associated with head space moisture condensation which results into moulding, hot spots development and caking of the grains (Talabi, 1996). Malawi being one of the tropical climate countries, high temperature variations inside the metallic silo may have a significant impact on the performance of the grain silos and consequently on the quality of the stored grains in these newly introduced grain metallic storage facilities. It is against this background that this study sets to investigate temperature changes within the metallic silos that may consequently inform on the quality of the stored grain. The evaluation was carried out in one of the districts of the country and between painted and non-painted small metallic silos.

1.2 General objectives

To assess the performance of painted versus non-painted small grain metallic silos in Malawi.

1.3 Specific objectives

1.3.1 To investigate temperature variations between painted and non-painted grain metallic small scale silos in Malawi.

1.3.2 To investigate the effect of painting on grain quality of maize stored for 120 days.

1.4 Research hypothesis

Ho_1: Inside temperature variations remain similar between painted and non-painted metallic silos.

Ho_2: The level of grain moulding and caking is similar between painted and non-painted metallic silos.

1.5 Rationale and significance of the study

While the small metallic grain silos have been dubbed effective in locking out post harvest pests and hence reducing losses, it is not yet very clear of what becomes of the quality of the grain after considerable long storage period in tropical regions. By painting the storage facilities with white paint, the study aims at finding out if such an improvement could enhance the performance of the facility by reducing the variations in inside temperatures. This is based on the premise that white coloured materials reflect light, hence we expect the painted facilities to retain less heat as opposed to the non-painted ones and therefore having better quality stored grain. By doing so, we believe its contributions shall be part of government's important efforts in ensuring a food secure Malawi.

CHAPTER TWO: REVIEW OF RELEVANT LITERATURE

2.1 Introduction

Losses of maize in storage is due to insect pests, rodents, mice, mites, thieves and increased temperatures which result into moulding and caking of the grains, Manickavasagan A. et al (2006). To address these problems small metallic silo technology has been put in place, although the novelty of the technology in the tropics and Malawi in particular, remains one of the major reasons for the inadequacy of relevant literature in the field. However, a few related studies that have been performed could still provide vital insights into this study.

2.2 Temperature variations in a storage silo

Alabadan and Oyewo (2005), focused on the comparative analysis of temperature variation within wooden and metallic grain silos under a typical tropical weather condition in Nigeria. In the study, temperature variations within and outside the silos were monitored for 130 days (July to November) during storage of maize.

Results showed that temperature variation within silo made from plywood was lower than temperature variations within metallic silo. This meant that the lower temperatures obtained from wooden silos would limit the activities of other deteriorating agents; reduce the development of hot spots and eliminate caking and moulding arising from moisture condensation.

Mijinyawa ,Y. et al (2007), concentrated on termite mound clay as material for grain silo construction. The study was carried out in a warm and humid climate in Nigeria. The major concern was the metallic silos which are the predominant structures used for grain storage but associated with moisture condensation problem which results in grain deterioration. Termite mound clay was identified as a potential material silo for construction. Temperatures were measured inside and outside the silo and the quality of grain stored in the silo was monitored over a period of 60 days. Viability tests of stored grain were also undertaken

Results showed that the temperature recordings within the silo were lower than the ambient temperatures. Results on grain quality showed that the grains neither gained nor lost moisture, maize seeds had no insect hole, maize shape remained intact, no evidence of rodents attack on the stored maize through traces of rodent's faeces. The last observation was on pre-storage viability which was 88 % and fell to 84 % after storage. According to Ellis, (1988), the level is well above 60 % which is the minimum recommended for seeds to be used for planting. Termite mound clay was then considered good for seed storage.

Alabadan (2002), did a study on evaluation of wooden silo during storage of maize (*Zea mays*) in humid tropical climate. This was after the author observed that, the commonly used metallic silos in Nigeria are susceptible to moisture condensation and unsuitable for the long-term storage of grain under the humid climatic conditions (FAO, 1995). Grain and ambient temperature measurements and silo evaluation were done for 9 months.

The author observed that the wooden silo was able to keep down temperature fluctuations within the silo interiors hence perform better in the tropics than steel silos. The results also indicated that there were no incidences of moisture condensation within the silo even with the higher wall temperatures. The author, from the findings, also states that colour of the silo structure have some influence on the radiant heat exchange between the silo and the environment. Following this, Yaciuk, 1975 states that white paint has considerable better radiation properties.

Bowszys, J. et al (2004), did a study on temperature distribution in seed mass stored in a metallic silo immediately after harvest. The silo was loaded with wheat grain, in August. Temperatures were recorded at four points located on the silo radius within a month after silo filling. Results showed that the highest temperature values and fluctuations were recorded at silo walls, so grains at this location are affected by inadequate storage conditions to the greatest degree, which may deteriorate its biological value and eating quality. The following suggestions were put forward to address the problem above; silo blankets should be insulated, to protect grain against considerable temperature rise and fluctuations resulting from a high rate of solar radiation energy, coat the cylindrical parts with paint (white) which reflects solar radiation, so as to decrease the temperature inside the silo during grain storage.

Morán et al (2004), did a study on effects of environmental temperature changes on steel silos. The following observations were seen by the authors: changes in the temperature along the silo wall which produced dilatations and contractions, which caused variations both in the wall stresses and in the grain pressures. These dilatations and contractions increased the modulus of elasticity of the grain, causing the stresses on the silo wall during the contractions to rise with each new cycle. Results obtained showed that drops of temperature greater than 20 K can provoke increases of pressures higher than the calculation values of eurocode (wind loads) in the upper zone of the silo, these increases are not proportional to drops of temperature and the increment is more pronounced as variations of temperature increase.

2.3 Moulding of grains in a storage silo

Navarro (2006), did a study on the mechanics and physics of modern grain aeration. His objective was grain aeration especially in subtropical and temperate climate in which diurnal or seasonal temperature fluctuations occur. One of the major factors he wanted to deal with was prevention of head space condensation. In this study he found that, under roof condition is a natural process than moisture migration within the grain bulk. Condensate that drops on the grain surface involves moisture in humid air that accumulates in the condition, which is acute in hot climates.

This is the primary factor limiting the introduction of bulk handling technology in tropical climates. The author continues to say that, average temperatures in the tropics are around 30^{o}C and the relative humidity fluctuates between 70-90 %. In the tropical climate, day and night temperature differences are very limited (usually not more than 5^{o}C) hence the problem arises due to heating of air at the headspace of the silo. The exposed metallic roof temperature can easily heat up to 50^{o}C or more, aggravating the condensation. Cooling the grains through operation of the ventilation system as what is done in temperate and subtropical regions is generally ineffective since the cooling effect of air with a day/night temperature difference of 5^{o}C is extremely low. Several attempts to adopt metallic silos for storage of paddy (rice) in Philippines have been made, but due to headspace moisture condensation which causes moulding and caking of the grains, even during short storage duration of 3 months, has made things impossible (Feed Technology Update, 2006).

Manickavasagan (2006) states that loss in quality and quantity in cereal grains, during storage is caused by fungi, insects, rodents and mites. Respiration may, in certain cases, contribute to a loss of dry matter during grain storage. However, the losses due to respiration are minor compared to those caused by living organisms. Fungi (moulds) are the major cause of spoilage in grain. Losses caused by fungi in cereal grains are related to; a decrease in germination, discolouration of the seed, heating and mustiness, biochemical changes, possible production of toxins, and loss in dry matter. There are two groups of mould that affect grain quality: field moulds and storage moulds.

Field moulds invade kernels while the grain is still in the field. These cause the discolouration of cereal grains often observed in plants exposed to very moist weather before harvest. In addition to affecting grain appearance, they cause a decrease in the germination of the grain seeds. Field mould damage is completed by the time the grain is harvested, and there is, therefore, relatively little that a producer can do about it. Once the grain is dried, these moulds die or become inactive.

Storage moulds are prevalent in storage facilities when the grain moisture content is too low for field moulds (less than about 20 %). The moisture and temperature requirements of these moulds determine the safe storage period (Manickavasagan A. et a,l 2006). In the process of controlling moisture content and temperature, mould growth is restricted and grain can be dried without significant spoilage. Grain temperature and moisture content determine the allowable storage time or how long grain can be kept before it spoils.

FAO (1970) says that moisture condensation problem which causes moulding of grains, is common in tropics particularly in areas where the sky is clear during both day and night. Though this is the case, a lot of metallic silo complexes exist in the tropics, often built without sufficient understanding of the unique problems of storing grain in this type of environment. A solution is needed to cope with air expansion due to fluctuation of temperature. The author’s recommendations from this observation was that, metallic silos should be painted white to reflect most of the incoming radiation during the day and also providing adequate shade to prevent large gains of heat energy in the grain. The other option was if the silo wall should be insulated.

Matumba (2009), did a study on effect of maize harvesting methods, storage conditions and flour preparation on aflatoxin incidence and human dietary exposure in Mpingu Extension area, Malawi. His study has also raised an alarm on aflatoxins which are metabolites of Aspergillus species (moulds) that frequently contaminate staple foods. It has been observed that smaller, repeated doses of aflatoxins gradually cause poisoning in people, elevate the risk of liver cancer and, in children, impair growth and immune system. The author continues to say that aflatoxin contamination arises from the nature of storage conditions where in some cases the following may be observed; excessive heat and humidity, insect and rodent damage resulting in proliferation and spread of fungi (moulds). These are the same moulds in the storage grains that contribute to hot spot development and later cake the grains.

2.4 Grain caking and hot spot development in the storage silo

A study was done by Jonfia-Essien, (2008) who looked at the capability of thermal imaging to detect a hot spot (a high temperature region) in an experimental silo (galvanized steel, 1.5 meters diameter and 1.5 meters height). The silo was filled with barley. An artificial heat source was placed at nine locations inside the grain bulk and set at four temperature levels (30°C, 40°C, 50°C, and 60°C) in each location. The outer surface of the silo wall and the top surface of the grain bulk were thermally imaged up to 48 hours at each treatment (n = 3)

Results showed that the temperature of the top surface of the grain bulk was significantly higher than the atmospheric temperature after 48 hours of hot spot establishment. The hot spot was detected from the thermal images of the silo wall and grain bulk, when it was located 0.3 meters from the silo wall and 0.3 meters below the grain surface, respectively. The hot spot was not detected on the thermal images of the silo wall when the wind velocities were 1.0, 1.5 and 2.0 m/s, and immediately after wind (n = 3). Similarly, thermal imaging did not detect the hot spot on the grain bulk when the ambient temperature was 1°C (hot spot = 30°C), and on silo wall when the ambient temperature was 8°C (hot spot = 60°C) (n = 3). It was also observed that the surface temperature of the grain bulk decreased with increasing moisture content.

2.5 Insect problem and efforts made to mitigate grain losses in storage

In 1968–1972 a study was made on losses of maize stored in villages in Malawi and different methods were tested to reduce these losses. Farmers were using cylindrical cribs made from bamboos or twigs to store the maize on the cob with the husks. Twenty-five cobs were sampled from the top layer of the crib. These were shelled and thoroughly mixed and then a sub-sample of about 700 grams was taken which was immediately fumigated. It was observed that infestation by pests such as *Sitophilus species* and *Sitotroga cerealella* started in the field. Considerable differences in susceptibility to insects between the maize varieties grown in Malawi were also noticed. Local varieties characterized by hard grains and a good husk cover were very resistant to insect damage. Several techniques were tested, to assess losses in the country which all, had their limitations and were in some way or another unsatisfactory.

Results in the laboratory showed that the percentage of bored grains was determined in a sub-sample of 1,000 grains. The overall loss of the 1971 crop caused by insects was very low (about 1%) because over 90% of the crop consisted of local varieties. Results from a survey conducted in a small area showed that the combined loss due to rodents, termites and moulds was about 1–3%. Overall results showed that, grain damage at the end of a storage period of 9 months was, in local varieties, about 10%; improved varieties showed after the same period a grain damage of 15–30%, while for certain varieties, which had very soft grains and a poor husk cover 70–90% of the grains were bored.

Efforts to mitigate the problem were made like use of 0.5 % Lindane dust as a protectant of maize cobs. This was found to be most effective when applied on cobs with husks. Lindane dust was made available to the farmers but had to be withdrawn because of possible incidences on the tobacco trade. Farmers were later advised to shell their maize during the dry season and mix it with malathion dust at 1 %. After sometime, it was discovered that use of insecticides, created problems. Recommendations on how to develop high yielding maize varieties which would be more resistant to storage pests were made. Another recommendation was made on how to make small silos which are insect proof.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.1 Selection of study area

Zomba district was conveniently selected in order to reduce transportation costs and also to effectively monitor the experiment. The experiment was carried out at Zomba Agricultural Station in the city of Zomba.

3.2 Source of maize

Twenty bags of MH 18 maize variety each weighing 50kg were obtained from Makoka Research station.

3.3 Source of metallic silos

These metallic silos made from galvanised iron sheets were constructed in Zomba city by the trained local artisans. In 2000, Malawi Government in collaboration with other development partners were involved in training local artisans with a purpose of making these silos locally available and easily accessed by small scale farmers. In Zomba city almost fourteen local artisans have been trained this is from a report given by one of the Crops Protection officers (Mr Matope), from Zomba Agriculture Station.

3.4 Drying of the maize grains

Maize grains were sun dried on simple reed mats. Both solar heat and natural ventilation were used to dry maize.

3.5 Moisture measurement

Moisture content of the grain at the time of storage is an important aspect to be considered as this prevents fungal activities. A digital moisture meter was used to measure and arrive at the recommended 11.5 % moisture content of the grain before storage (Muhindi, 2008).

3.6 Installation of metallic silos

Four small grain metallic silos of 250 kilograms capacity were installed at this station. Two were painted white (using rainbow paint), and the other not painted. Each silo was filled with 250 kilograms of MH 18 maize variety (Zea Mays) at 11.5 % moisture content (wet basis). Hence, a capacity of 1,000 kg of shelled corn was considered adequate for this study. The cleaned, weighed and sound maize grains were stored in the silos, which were then tightly closed. These metallic grain silos were placed under a shed.

3.7 Measurement of temperature

The procedure for measuring temperature was adopted from Alabadan, (2002). Temperature readings from inside the silos were measured using a HOBO U12 4 - External Data Logger; Onset Computer (Figure 4 in appendix). These were permanently inserted at three points inside the storage silos for a period of about 120 days.

The thermometer sensors were set at the centre of the silos, at the silo wall, and at the top of the metallic silos (grain surface) where they were left hanging to measure the temperature of the air space above the grain surface, Alabadan, (2002). Temperature readings were recorded externally by the data loggers that were safely hung outside the silo but joined to the sensors inside by the chord (e.g. figure 4).

This ensured no disturbances to the air inside the silo. The installation of thermometers were done in a way that maintains the principle of metallic silos, which are supposed to be air tight always to minimize the levels of oxygen

Temperature from each silo, was measured using a special thermometer mentioned above which registers almost 43,000 measurements. The logger uses a direct USB interface for launching and readout in a HOBO ware computer package. This means that they have the potential to transmit the data to the computer on a daily basis. Temperatures at all measuring points were automatically recorded at one-hour interval while sensors were in place. Outside temperature of the silos was collected from the nearest weather station, Chancellor College, Geography Department in these months of storing the grains.

3.8 Sampling of stored maize in the four metallic silos for quality examination

Sampling was done in three points in the silos in respective to where the sensors were placed that is to say on the grain surface, at the centre of the silo and at the silo wall. A 1 kg sample was procured around each sensor following Michael, (2005). To arrive at desired depth where sensors were placed grains were removed from top of the silo in layers.

3.9 Observation of grain quality

The quality of the grain was observed at the end of the study period. The grain was classified into sound, mouldy and caked, and this was expressed in percentages of weight. Moulding results from moisture condensation and this was detected from the external colour if grains were black.

A musty or mouldy odor indicated the beginning of a storage problem and fermented or sour odor indicated a serious problem (Jergenson, 2006).

Grain caking was detected from the external colour of the grains too, if it was brown accompanied by a tobacco-like odor, this indicated metallic silo burn (Jergenson, 2006).

3.10 Analysis of data

Data was transferred and managed in excel where cleaning and charts were drawn. Other statistical analysis was performed in SPSS (11.0 for windows). Analysis of temperature variations inside the silo was first explored using daily average temperature plots. Igbeka, (1983), states that a weekly rise in temperature of only 3-4 ^{o}c will indicate a possible problem.The manually graded sound, moulded and caked grains were calculated in percentages of weight. Independent Samples T-test was employed to ascertain the differences in temperature variations between white painted and non-painted silos. Analysis of Variance was used to ascertain if there was a significance difference in the temperature readings on different positions (top, centre and wall). The tests were performed at 5 % significance level.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the results on temperature variations inside the metal silos through daily temperature plots, independent samples t-test, analysis of variance and also results on grain quality.

4.2 Effect of painting on temperature in the silos

This section is showing the results on the effect of painting on temperature inside the metal silos.

4.2.1 Daily temperature plots

The daily recorded temperatures in both painted and non-painted metal silos were plotted in graphs as shown below;

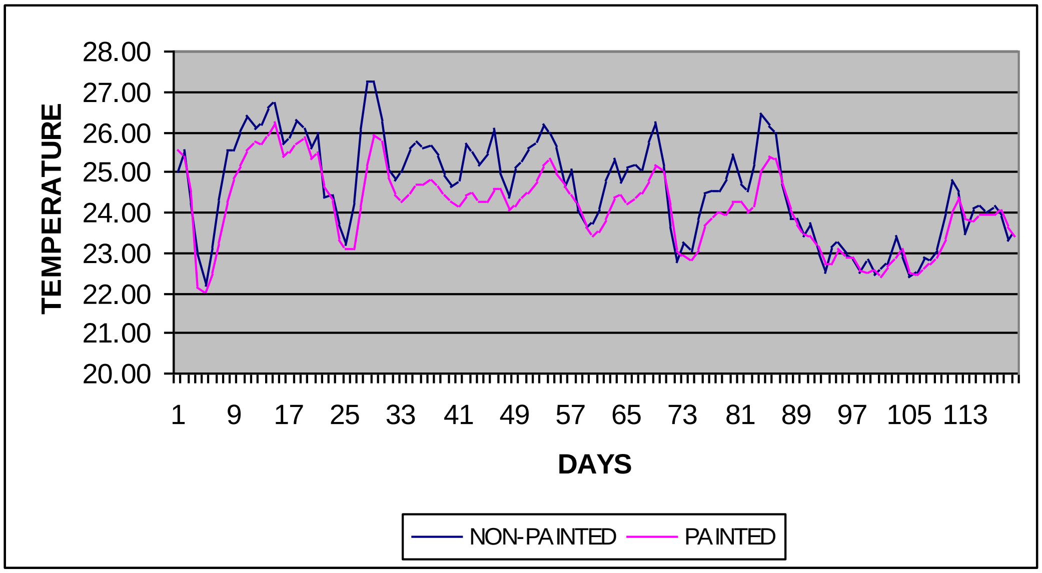

Figure 1: Plot of daily mean temperature in degrees Celsius of silo top between painted and non painted silos

Temperatures for non-painted metallic silo are consistently higher than those in white painted metallic silo in the graph above. This clearly shows that painting has an effect on the inside temperature of the silos. This trend is not only seen at the top of the silo but also at the centre and wall of the silos as shown in figure 4.2 and 4.3 below.

It has also been observed that there is the rising and falling of the temperature in the graphs. This can be as a result of the nature of rains that Malawi as one of the tropical countries receives. Most precipitation in the tropical countries appears to be convective. Convectional rainfall occurs when the energy of the sun heats the earth's surface and causes water to evaporate changing to water vapour. This moist air rises and as it rises it cools. The air reaches condensation level where it has cooled such an extent that the water vapour condenses and turns back to liquid form. Later rain falls. This process repeats itself hence the rising and falling of temperatures in the graphs which seems to form some cycles. In Malawi this occurs from the month of October up to December or early January (Agnew, 1972).

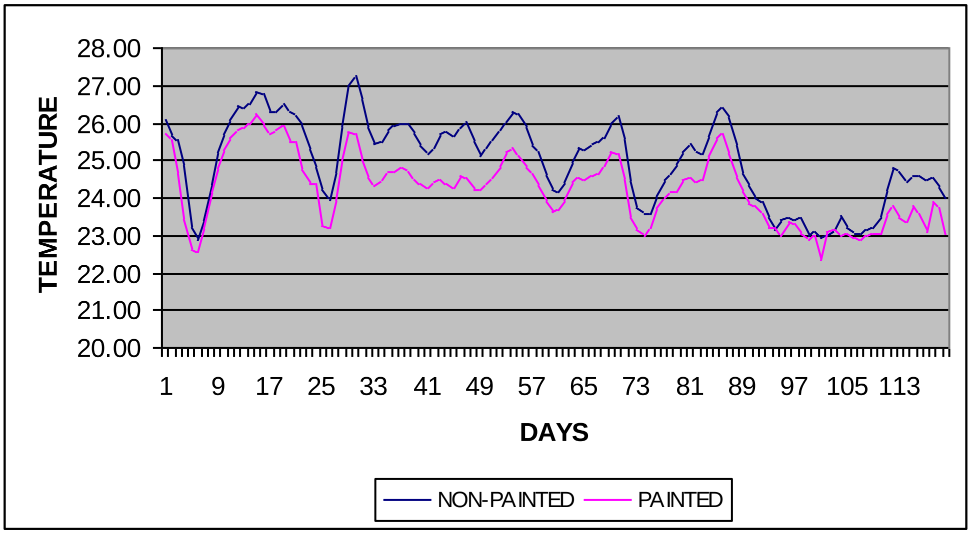

Figure 2: Plot of daily mean temperature in degrees Celsius of silo centre between painted and non painted silos

Temperatures within the non-painted metallic silo are generally higher than those within the white painted metallic silo with up to 0.9°C in figure 4.2. The maximum and minimum temperatures within the non-painted metallic silo are 27.24°C (day 30) and 22.99°C (day 100) while that of the white painted metallic silo are 26.38°C (day 13) and 22.96°C (day 106).

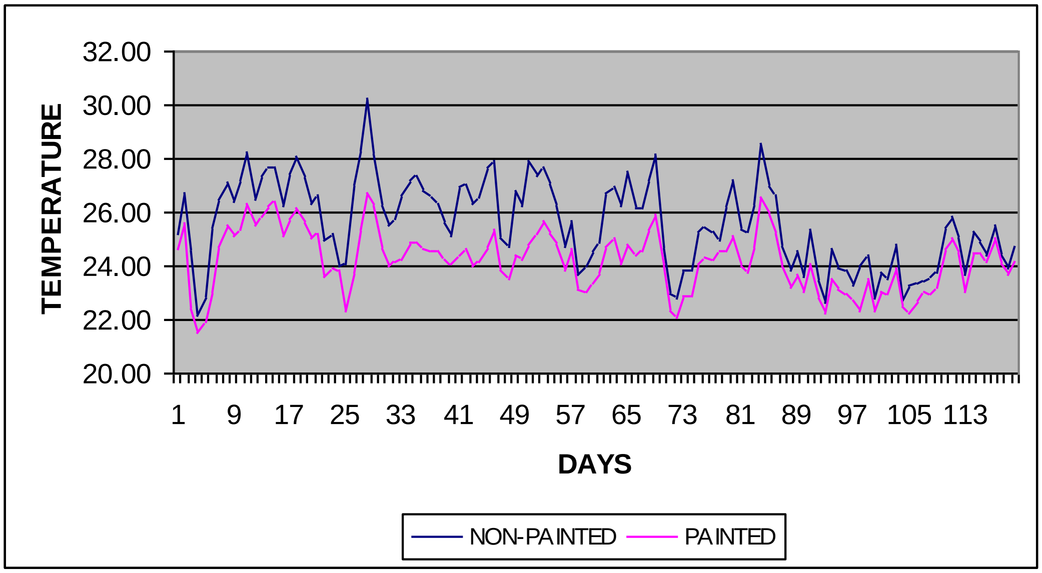

Figure 3: Plot of daily mean temperature in degrees Celsius of silo wall between painted and non painted silos

The temperature at the walls of the non-painted metallic silo is generally higher than those of painted metallic silo as shown in Figure 4.3. The trend could be attributed to the fact that white paint on the painted metallic silo has a low thermal conductivity than the non-painted metallic silo which is just like any other metal; consequently heat is retained at the non-painted metallic silo wall more than the white painted metallic silo wall that would lead to the accumulation of heat. This made it possible for white painted metallic silo to be able to maintain low temperatures throughout the storage period.

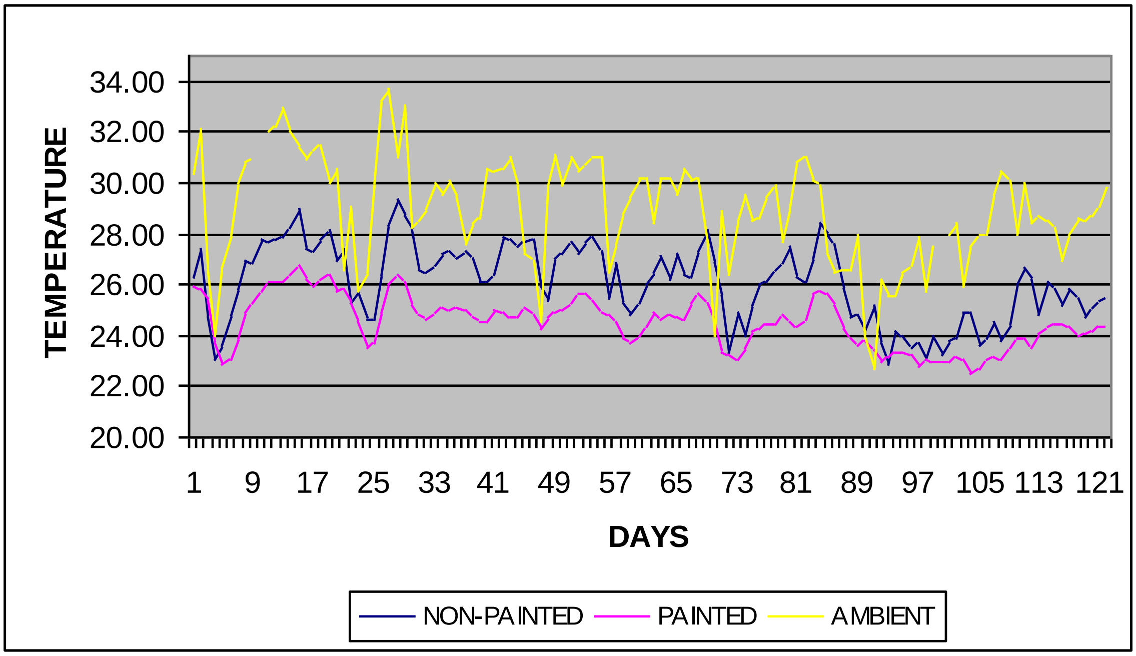

Figure 4: Plot of silo top maximum temperatures in degrees Celsius for painted and non painted silos (including ambient)

The results from the graph above show that the temperatures of non-painted metallic silo are higher than those of painted metallic silo, though the ambient temperatures are highest to both white painted and non-painted silo temperatures. (Feed Technology updates, 2006), states that high prevailing daytime temperatures enhances heat build-up at the headspace of the grain bulk which causes moulding and caking of the grains. In this case the highest temperatures are those from ambient and the lowest from white painted metallic silo. This really means that there is reduced heat build-up at the headspace of the painted metallic silos hence reduced levels of grain moulding and caking.

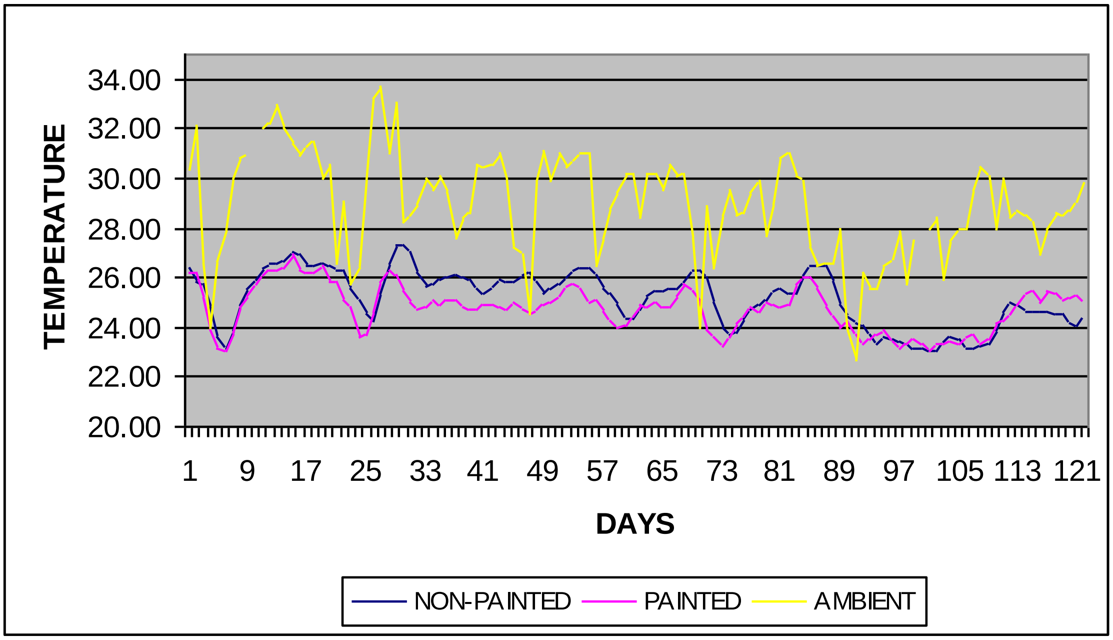

Figure 5: Plot of silo centre maximum temperatures in degrees Celsius for painted and non painted silos (including ambient)

The temperatures of non-painted silo are generally higher than those of white painted silo, but again ambient temperatures are generally highest to both white painted and non-painted silo temperatures in Figure 4.5. This could be as a result of no insect infestation which could have raised the temperatures at the centre of both silos and sub-due that of the ambient (Chang et al., 1993). This can be linked with the principal of metallic silos as they are made in such a way that they are airtight, therefore minimizing oxygen and killing any weevils or pests that may be inside, (Malawi Government, 2006). The generally lowest observed temperatures of the white painted silo provide a conducive environment for the stored grain, hence maintaining its quality.

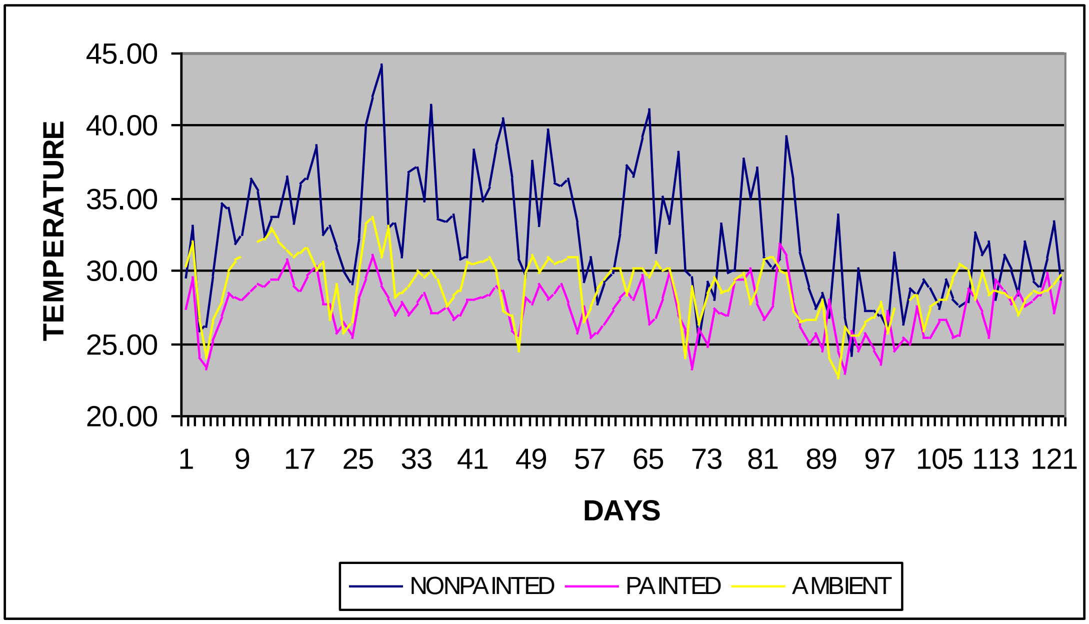

Figure 6: Plot of silo wall maximum temperatures in degrees Celsius for painted and non painted silos (including ambient)

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Temperatures of non-painted metallic silo are much higher than those of painted metallic silo and the ambient in figure 4.6. This is not strange because Novarro, (2004) reported that the temperatures inside the metallic silos can go upto 50 ^{O}C or more. Bowszys (2004), further stated that the highest temperature values and fluctuations can be recorded at silo walls, so the grain placed there is affected by inadequate storage conditions to the greatest degree, which may deteriorate its biological value and eating quality. This result portrays desirable implications of painting of the metallic silo. The low observed temperatures in white painted silo should provide a conducive environment for the stored grain, hence maintaining its quality.

4.2.2 Comparison of daily mean temperature readings between non-painted and painted metallic silos (top, centre and wall) -using an independent samples t-test

An Independent samples t-test was used to compare the average temperature readings between the white painted and non-painted grain metallic silos. The Levene's test for equality of sample variances (F= 8.075, p- value = 0.005) indicated that we cannot assume equal sample variances in our t-test calculations.

Therefore, the t-test assuming non-equal sample variances was employed (see appendix 5). Table 4.1 shows results of an Independent Samples t-test for Top, Centre and Silo Wall readings. The p-values obtained from the t-test indicate evidence of a significant difference in all cases, (that is, Top, Centre and Silo Wall readings).

The mean differences in all cases show that the average mean temperatures were generally higher for the non-painted silos than the white painted silos. On the top of the silo, the mean difference ranged from about 0.15 to 0.72 degrees Celsius, while that of the centre ranged from 0.27 to 0.81 degrees Celsius and that of silo walls ranged from 0.96 to 1.69 degrees Celsius. The mean difference was highest for the wall readings seconded by top readings, and the lowest was for the centre readings.

These results generally indicate that painting had an effect in controlling inside silo temperatures. In so doing, this meant creating a much improved and better storage condition for the maize grain.

Table 4.1: Comparison of Daily Mean Temperature Readings Between Non-Painted and White Painted Metallic Silos (Top, Centre and Wall) - Using Independent Samples t-test

Position	Difference	Mean Difference	95% CI	T-value	DF*	P- value
TOP	Non-painted-Painted	0.434	(0.15, 0.72)	2.97	230.7	0.005
CENTER	Non-painted-Painted	0.541	(0.27, 0.81)	4	233.7	0.000
WALL	Non-painted-Painted	1.33	(0.96, 1.69)	7.16	222.7	0.000

* Calculated using Welch-Satterthwaite equation (see appendix 5)

Analysis of Variance was carried out to ascertain if there was a significance difference in the temperature readings on different positions. Results show an evidence of significance difference in all cases (Top, Centre and Wall) with p-value 0.000. This means that there is some temperature difference in these positions. To identify at which positions we have these temperature differences, a post hoc test was performed using LSD. Results from table 4.2 show that there were temperature differences between, top and centre, top and wall and also between center and wall. The negative mean differences in the table show that the temperature readings from top and centre (I) position were lower than that from centre and wall (J) positions, in this case the temperature readings from the top position of the metallic silos were lower than that from the centre and wall positions and also the temperature readings from the centre of the metallic silos were lower than those from the wall position of the metallic silos.

Table 4.2: Comparison of Daily Mean Temperature Readings Among Metallic Silo Positions (Top, Centre and Wall) – ANOVA- (LSD)

(I) Position – (J) Position	Mean Difference (I –J)	P- value
Top - Centre	- 0.316	0.005
Top – Wall	- 0.535	0.000
Centre - Wall	- 0.219	0.000

BETWEEN POSITIONS ANOVA (p = 0.000)

The t-test and ANOVA results are very much in agreement and confirm what has already been observed in the temperature plots above.

4.3 Results on grain quality

This section is showing results on grain quality where the stored grains in the painted and non-painted silos were graded into caked, moulded and sound at the end of the study.

4.3.1 Results of grain quality based on percentage of weight

This part shows the manually graded sound, moulded and caked grains in percentages of weight.Results of grain quality have been calculated on percentage of weight, following an example from Mijinyawa, (2007). This was calculated using the formula below:

$$P = w/W * 100\%$$

where;

P = percent of sample with a particular attribute (caked or moulded) from a specified location (top, centre or wall).

w = weight of a sample with a particular attribute from a specified location in kg.

W = Total weight of the sample from each location (conveniently set to 1 kg).

Table 4.3: Percentages of caked /moulded grains per 1kg sample of grains from top, center and silo walls

	CAKED			MOULDED		
	TOP	CENTRE	WALL	TOP	CENTRE	WALL
PAINTED SILO	1.10	1.00	0.09	0.10	0.00	0.50
NON-PAINTED SILO	18.5	12.0	30.0	1.50	0.50	1.50

Results from table 4:3 show that percentages of caked and moulded grains in non-painted metallic silo are much higher in all cases, (that is, Top, Centre and Silo Wall readings), than those of painted silo. More grain caking has been observed on the wall of the non-painted silo (30%), where high temperatures have been experienced, seconded by top position (18.5%), where moisture condensation is experienced, due to increased temperatures which cause headspace moisture condensation problem which is common in tropical countries like Malawi.

An increased percentage of moulded grains are from top and wall of the non-painted silo (1.5%). This could be due to the same problem of headspace moisture condensation, where water-droplets, drip onto the top surface layer of the grain bulk and later along the walls causing the moulds to grow, (Feed Technology Update, 2006).

Generally observations showed that silo locations with high temperatures are the same areas where increased level of caking and moulding of grains are experienced and this was more in non-painted silos than in painted silos. This is an indication that the painted metallic silo is able to maintain the quality of the stored grain.

4.4 Limitation of the study

The results seen above present interesting finding. Though this being the case, the study is not without limitations. Firstly, the study was performed in one location. This makes it difficult to generalize the results to a larger part of Malawi, which we are aware could have slightly different agro ecological zones compared to the study location. Secondly, due to financial limitations, the study only had two replications per group (i.e. painted or non-painted). This may limit the power of the results and hence compromise the implications drawn from the findings. Notwithstanding these limitations, there is still this conviction that the study results remain useful and informative.

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study was set to investigate the comparative performance of painted and non-painted metallic grain storage facilities on maize grain. Exploration has been done on temperature variation, moulding and caking between painted and non-painted metallic silos. Higher temperatures have been constantly observed in non-painted silos. This was true in all silo locations. These results were consistent when using graphs or under t-test and ANOVA. Caking and moulding has also been pronounced in non-painted silos. To a greater extent, this was more adverse on the silo walls. These results provide clear evidence that white painted small grain metallic silos were able to stabilize temperature variation, and as a result maintaining the quality of the grain.

Therefore, an observation has been made that while there is clear evidence of the metallic silos to lock out the pests, white painting of the silo would greatly improve its performance in regions similar to the study area. In this regard, white painting of small metallic grain silos would be highly recommended to all small scale farmers in similar tropical conditions that have been studied.

5.2 Recommendations

In view of the findings above, one would easily recommend an improvement on the metallic silos by painting them white. However, to give more credibility to the findings, we believe further research covering many locations in Malawi (e.g. in different agro-ecological zones) would be a necessary thing to do. In addition, a reasonable number of metallic silo replications might be worth considering.

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APENDICES

Appendix 1: Traditional cribs and gunny bags (Julia et al, 2006) and (Haris et al 1976).

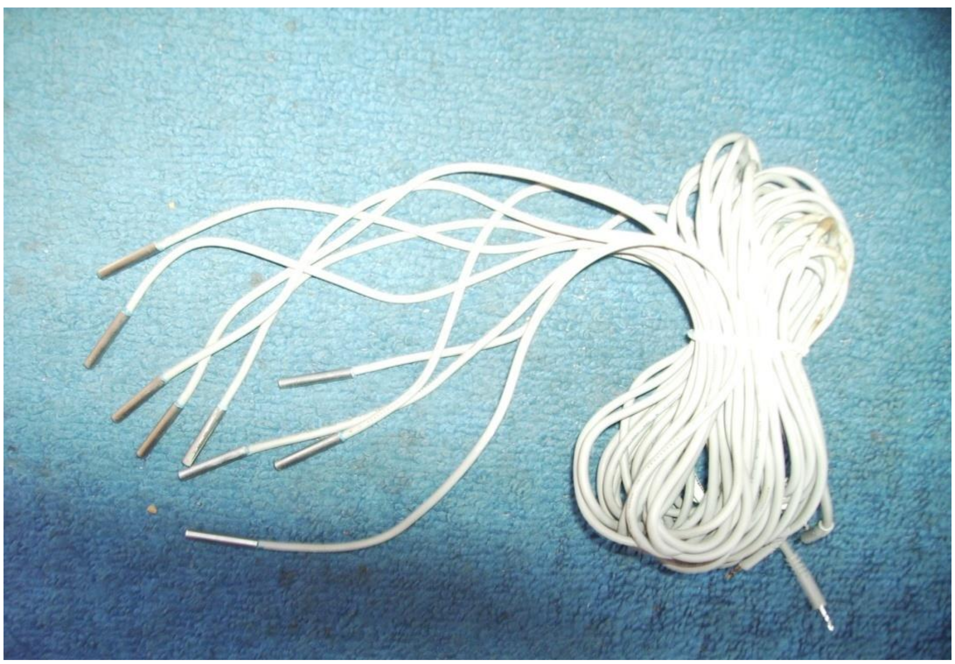
Circular Crib | Rectangular Crib

Gunny Bags

Appendix 2: Maize grains attacked by Large Grain Borers (Levigne, R., J. (1987).

Appendix 3: Small metallic silos

Appendix 4: HOBO Data loggers and Thermometer sensors with their chords



Appendix 5: Independent sample t-test formula

$$t = \frac{\bar{X} - \bar{Y}}{\sqrt{\frac{s_X^2}{m} + \frac{s_Y^2}{n}}}$$

Appendix 6: Welch-Satterthwaite equation for calculation of degrees of freedom

$$DF = \frac{\left({S_X^2}/{m} + {S_Y^2}/{n} \right)^2}{\left({S_X^2}/{m} \right)^2 /(m-1) + \left({S_Y^2}/{n} \right)^2 /(n-1)}$$

In both Appendix 5 and 6, X represents non-painted silo, Y represents the painted silo observations.

m and *n* represents samples sizes for non-painted and painted silo observations respectively.

s_X^2 and s_Y^2 represent sample variances for non-painted and painted silo observations respectively.