# TEMPERATURE AND RELATIVE HUMIDITY EVALUATION ON STORED MAIZE IN METALLIC GRAIN SILO

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**MATRIC No. 2004/18337EA**

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**FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA**

**JANUARY, 2011.**

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL & BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

JANUARY, 2011.

# DECLARATION

I hereby declare that this work is a record of determination and evaluation which were undertaken by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished work were duly referenced in the text.

ABUBAKAR AHMED SHERIFF — 12/4/2011

| Name of Student | Signature and Date |
|---|---|

## CERTIFICATION

This is to certify that this project entitled "Temperature and Relative Humidity Evaluation On Stored Maize in Metallic Grain Silo" by Abubakar, Ahmed Sheriff, meets the regulations governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

| | |
|---|---|
| Engr. Prof. B. A. Alabadan<br>(Supervisor) | 21/01/11<br>Date |
| Engr. Dr. A. A. Balami<br>(Head of Department) | 21/01/2011<br>Date |
| External Examiner | 13/01/2011<br>Date |

# DEDICATION

This project is dedicated to the Almighty Allah (S.W.T), the Beneficent and the most Merciful who has spared my life up to the concluding part of this academic pursuit, and I also dedicate this project work to my late Mother Nana Hawau Abubakar, and my Father Alh. Siriu Ahmad Abubakar who for many years has struggled and faced many odds to see that I attain academic Excellence.

# ACKNOWLEDGEMENTS

I would like to express my profound gratitude and appreciation to Almighty Allah, the beneficent and the most merciful for sparing my life through the completion of the academic pursuit. To him are the glory, majesty and honour for ever. Words cannot express my profound but unreserved gratitude for the valuable suggestion and critism rendered by my project Supervisor Engr. Prof. B.A Alabadan, his valuable and guidance have enhanced my further understanding of the topic and helped me in putting this project into its present shape. A well deserved thanks goes to my lectures: Engr. Dr. A.A Balami (H.O.D Agricultural and Bio-resources Engineering Department), Professor N.I Itodo ,Engr. Dr. Mrs Z.D Osunde, Engr. Dr. D. Adgidzi, Engr. Dr. N. Egharevba, Engr. Dr. O. chukwu, Engr. Dr. P.A idah, Dr. M .Y Otache, Engr. Dr. Agidi, Engr. Mrs. H.I Mustapha, Mr. P.A. Adeoye, Mr. Solomon. M. Dauda, Mr. J.J Musa, Mr. Moh'd. A. sadeeq Mr. Adamu Halilu, Mrs Bosede Orhevba, Mr. Olorunsogo Samuel, Mr. Segun E. Adebayo, Mr. O.A Fabunmi, Alh. M.S Sulaiman (Chief Technologist), Engr. Isyaku A. Moh'd, Mal. Saidu Zegi, Mal. Abdullahi Adamu, Mal. Aliyu G. Garba, Mr. Kehinde Bello, Mr. Aliyu U. Kabir and Mrs Helen Omale for their stimulating lectures which has contributed to the success of this project. My thanks also goes to my father, Alh. Siriu Ahmad Abubakar for his moral and financial support during the years of study. My sincere and profound gratitude goes to my messiah and role model Matron Amina Isah (Snr. Matron General Hospital Minna, Niger State.), for her endless support. My sincere appreciation goes to Alh. Abdulwahab Agbomabini Arije, Mr. Wale Mustapha (M.D Crane advertising Ltd.Lagos), my Uncles: Alh. Muhammad Boboli Abubakar (Magaji Jubilee Community), Mal. Muhammad Habiu Abubakar, Mal. Muhammad Abubakar( Baaba Bale), Mal. Tijani Abubakar, Mal. Abdulkadir Abubakar, Mal. Bube, and my Inlaw, Mal. Sulaiman Ishaq, and my Daddy's late Uncle Alh. Ahmad Akibu Mangoroa, my step

Mothers: Hajia Shakirat Abubakar, Hajia Haolat Abubakar( Iya Shehu), and Aishat Abubakar, my lovely sister Mariam Abubakar, my cousin Brothers: Mal. Abubkar Abubakar (Alfa), Mamma Habibu Abubakar (Mamma Maimu), my mentor and Brother, Mal. Mukhtar Abdulkadir (Chemical Engineer), my friend and Brother, Danladi Ahmed Isah (Automobile Engineer), and my friend indeed, Abubakar Abdulkadir Gana. My special thanks and appreciation goes to my colleague and friend Mary Bunmi Adebayo, for her support and assistance rendered. And to the rest of my extended family members, friends and colleagues for their encouragement, moral, financial support, love and affection during the course of study.

# ABSTRACT

The aim of this project was to evaluate the temperature and relative humidity of maize stored in a metallic grain silo over a period of three months under tropical climate. A one tonne capacity, 0.96 m diameter and 1.95 m height cylindrical metallic grain silo was used and erected in Minna. The silo was made of galvanized mild steel and it had three access point, a loading point (door) on the top of the silo, two discharge points located on the wall at the middle and bottom wall of the silo. The silo floor rested on wooden pile foundation and it was kept inside the departmental laboratory. Grain determination and evaluation were done for three months. At the end of the three months of storage, the temperature and relative humidity did not amount to high moisture content which can lead to grain caking, mould growth and other defects which are associated with high moisture content.

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# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 BACKGROUND TO THE STUDY

Grain silo is a storage tower or structure used or designed to store Agricultural grains or produces such as guinea corn, threshed rice, shelled maize and so on. This is done so that there will be assurance of food supply at all season of the year. Some of these grains after harvest will be stored commercially while others will go to the market for sale as well as stored on the farm.

For any nation to achieve self-sufficiency not only must crop yield be increased, but regular returns must be ensured. This arise the need for storage (Lasisi, 1975).

In Nigeria, a wide variety of Agricultural products are being produced ranging from cereal grains (such as rice, sorghum, maize) to roots and tubers (such as cassava and yam) to vegetables and fruits and a host of dairy products (Ashafu, 1986). In the northern part of the country, maize is the principal food crop for the people that is been grown and the demand for it is all year round, but it can only be produced within a certain period of the year. More so, there is need to store some of the grains so that there will be continuous supply for the people all through the year regardless of the season.

In the tropics, there are serious losses of farm produce particularly grains before, during and after harvest. Lack of adequate storage facilities is one of the major reasons for the shortage of food grains in the tropical countries and also through insect infestation, attacks by rats, birds and some other micro-organism. Owing to these, farmers are forced to keep a small portion of their grains and take the rest to the market at a reduced loss of stored Agricultural produce and enhance marketing efficiency and to meet demand, which is evenly spread throughout the year (Igbeka, 1983).

More so, large scale producers require large storage facilities for their products. Therefore, there is the need to design a farm grain structure that will be suitable for storing grains produced in large quantity. The choice of materials also depends on the environment and the technology needed to install the structure. Hence the need for the design and construction of the metal silo, which will be more advantageous than the wooden silo, came up using metallic material such as aluminium or steel to meet the need of the local farmers.

### 1.2 STATEMENT OF PROBLEM

One of the most acceptable methods for storing grains on a large scale is the use of the silo, made from different materials like Aluminium, Steel, Wood or Concrete. Due to the humid climate in Nigeria, the wide diurnal (daily) range in temperature results in excessive heating on the metallic silo roofs and walls and its distribution with the bulk grain as well as moisture condensation. This results to grain caking, development of hot spots, mould growth, seed germination and rapid developments of insects. This usually results in the short–term grains product storage as well as high deterioration of grains.

In a way to put a check on this or fight this problem, the Federal Government of Nigeria in 1990 (Laban, 1990) embarked on a 250,000 Tons Strategic Grain Reserve using metallic silo in all the state of the Country. Under the Nigerian climatic condition these metal silos have been found to have defects such as grains dampness, caking of grains, development of hot spots, this leads to mould growth and are associated with high importation cost, technical and management problem.

## 1.3 AIMS AND OBJECTIVES

This project's objective is to evaluate the one metric tonne capacity metallic silo over a storage period of three months. And it is aimed at:

1. Evaluating temperature variation of the maize inside the silo.
2. Evaluating the relative humidity of the maize environs inside the silo.

## 1.4 JUSTIFICATION OF STUDY

There are silos constructed of other materials like woods, concrete, laterite, rubber and other synthetic materials which can be of good use for the purpose of storage of grains. The use of the metallic silo in the storage of grains has been constructed due to its advantage over the wooden type of silo for its resistance to rodent attack and the facility to control insects by fumigation. More so, the silo cannot be attacked by an insect like termite when compared to the use of wooden silo. When kept under shade at room temperature the effect of direct sunlight on the silo will be reduced, thereby avoiding excessive heating on the metallic silo and all other consequences that might follow.

## 1.5 SCOPE OF STUDY

This project work is limited to the evaluation of temperature and relative humidity changes inside the metallic grain silo.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 The Purpose of Storage

Storage has to do with the collection and the keeping of the Agricultural produce that are not presently in use for future use in structures in which the adequate control of the environment in order to maintain the quality of the product. Storage is also an interim in the complex logistics of transporting agricultural produce durable and semi-perishable from producer to processor and its products from processor to consumer.

Products of agriculture need to be stored from one harvest to the next even to the time of their need. Storage is important because naturally agricultural materials are hygroscopic (that is can absorb or give out moisture) and are always in dynamic equilibrium with their environments.

The economics of storage create the need for way to accumulate goods for subsequent distribution to the market place on basis of fluctuation demand. If all products were manufactured as they were ordered rather than held in large quantities for possible future sales. There would be little need for storage.

### 2.2 Conditions That Affects Safe Storage

#### 2.2.1 Moisture content

Moisture content is the quantity of water that is contained in material. Before taking any measure, there are certain percentages of moisture content required for each crop. For example, high moisture grain determines fast due to high equilibrium relative humidity (70%) of the inter seed air inside the grain. This condition encourages the growth of micro flora.

Heat and more moisture are further produced by the respiration of the micro flora and the grain itself which leads to further complication. High moisture grain that is self-heating often results in uncontrolled temperature to the point of ignition and spontaneous combustion. This immediately destroys the grain with continuous mould growth.

Recommended moisture content levels for safe storage are tabulated below:

**Table 2.1: Recommended moisture content levels for safe storage.**

| **Crop** | **M.C at harvest (wb)** | **Required M.C for safe storage for 1 year** |
|---|---|---|
| *Maize* | 24-30 | 13 |
| *Rice* | 20-24 | 14 |
| *Wheat* | 17 | 13-14 |
| *Oats* | 18 | 13 |
| *Soya beans* | 20 | 11 |
| *Hay (grass)* | 70-80 | 20-25 |

Chukwu, 2001.

### 2.2.2 Temperature

Temperature is the degree of hotness or coldness of a body or environment (corresponding to its molecular activity).

Temperature in the range of $5^0$-$10^0$C are considered most desirable for save long term storage of grain. At these temperatures, the respiration rate is low, insect activity is reduced since most insect species are unable to reproduce at temperatures below $10^0$C. Achieving and maintaining such low temperatures in storage brings about technical and economic problem.

"Chilling injury" being brought about by low temperature induces storage disorders in certain materials. For example, yam tissue is said to suffer excessive decay at or a temperature below $12^0C$ when the tissue or tuber is exposed to ambient conditions.

## 2.3 Evaluation of Grain Storage Structure and Methods

### 2.3.1 Low-level grain storage

Village level storage is another name used for low level grain storage and there are several types of traditional storage structure used by farmers for storing their grains each adapting to the climate of the country and these are usually made out of locally available materials.

Cribs of various types are used by maize farmers and these cribs are of poor facilities for continuous drying of maize and insect control. An improved maize crib has therefore been designed for use by farmers for effective storage in maize at lower level. This is mainly done by mixing small quantities of cement with the earth or careful finishing or smoothing of the silo walls.

### 2.3.2 Middle level grain storage

At the middle level grain storage, the use of sacks and rhombus are found.

1. **Sacks:** This form of storage is very common with retailers and markets and so its mostly used for storing shelled produced in bags which are shocked and are usually on raved planks in stores, barn or houses.
2. **Rhombus:** This is another example of middle level grain storage. Many physical structures can be identified with the rhombus. The rhombus could be either roughly cylindrical in shape or flask shaped tapering at one end. Damages by rain torrents, rodents, accessibility are both reduced and avoided by slightly raising the floor of the rhombus.

### 2.3.3 High level grain storage

High level grain storage is complex storage structures intended for the commercial storage of large quantities (several thousand of tonnes) of produce.

The silo is the commonest type of high level grain storage and specialized builder offer various types of silos, two, in particular.

i. Vertical silos
ii. Horizontal silos

The vertical silos are mainly made up to several sheet metal or reinforced concrete storage bins stacked vertically.

The horizontal silos are made of sheet metal or concrete and are composed of juxtaposed square or rectangular bins laid horizontal.

High level grain storage as these should be equipped with ventilation system backed up by temperature controls; all these are to avoid the disadvantages of potential rise in temperature, and to guarantee good storage.

In term of storage, these ventilation systems can have the following effects:

1. To lower the temperature of the grain in order to slow down biochemical degradation process (cooling ventilation)
2. To keep the grain at a constant temperature, by systematically evacuating the heart produced by the grain mass itself (maintenance ventilation)
3. To dry the grain slowly.

### 2.3.4 Commercial level grain storage

Grain storage in this level is carried out by large scale grades, exporters, agro-based and allied companies, government agencies and some of the few existing large scale farmers.

The structures of this storage method are large due to the high rate of production as well as long lasting and permanent and they are mainly silos or warehouse.

## 2.4 Silo

Silos are storage structure in which grains can be stored loosely in bulk without putting them in bags or sacks. Before the grains are finally stored in the silos they are stored in sacks by the production and precautions have to be taken to ensure the safety of the grain and maintain its quality.

The problem of condensation and moisture migration has being a serious one in Nigeria which has militated against the use of metal conventional silo for grain storage. Nevertheless, heavy losses have not been recorded when grains are put in the silos, insect control is achieved by the use of suitable fumigants. Only dry grains of about 13% moisture content can be safely stored in silos. Any one above this is liable to the problem of condensation moisture migration and even insect damage.

Improvement that have been introduced to silo storage including making them air tight, shading them on top with palm tree leaves or grass and also using Nitrogen atmosphere to protect the grains stored this will completely solve the problem of condensation moisture migration and insect damage.

### 2.4.1 History, development and underlying problem of silo in Nigeria

In Nigeria, the use of silos as grain storage structure start back tots the mid-1950s. The first silo in Nigeria was a twenty-tonne aluminium type enacted at Ilaro in Ogun State. (Williams, 1971).

The extension service division of the Ministry of Agriculture and Natural Resources of the Western state coordinated the grain storage programme of the Western Nigeria and they were responsible in helping the farmers store their grains during the period of low crisis and release them to the market when the prices were not favourable. Silos were made free of charge for farmer's use through the United State Agricultural Department in conjunction with the grain storage programme of Western Nigeria. Since the use of the large volume imported silos did not meet the requirement of the small-scale farmers in Nigeria due the cost of acquisition and maintenance.

### 2.4.2 Type of silo

#### 2.4.2.1 Alternative solid wall bins

a. The "BURKINO" silo

b. The "PUSA" bin

c. The USAID" silo

d. The Ferrocement bin

e. The Synthetic silos (plastic and rubber silo)

**The "burkino" silo**

This silo is constructed with stabilized earth bricks based on a traditional dome shaped type of bin, in which various models and capacities are available. The shaped root is made of stabilized earth bricks, using special wooden formers. The base is also made of stabilized earth resting on the ground or on concrete pillars.

Skilled masons are the ones that usually make a doom-shaped roof because its technique is not easy to master. A variant has been developed with the roof resting upon a wooden frame, which can be erected by unskilled farmers.

**The "pusa" bin**

These silos are made of earth or sun-dried bricks; that are rectangular in shape and have capacity of 1 to 3 tonnes. This was developed by the Agricultural Research Institute (I.A.R.I)

A typical "Pusa" bin has a foundation of bricks, stabilized earth or compacted earth. A polyethylene sheet is laid on this, followed by a concrete slab floor 10cm thick. An internal wall of the desired height (usually 1.5 to 2 meters) is constructed of brick or compacted earth, with a sheet of polyethylene wrapped around it. This sheet is heat sealed to the basal sheet before the external wall is then erected. An outlet pipe is built into its base during the measuring 60 × 60cm is built into one corner.

As the Pusa bin has been widely adopted in India, it has also been demonstrated in some African countries. When loaded with well dried grain it has been given good result.

**The "USAID" silo**

The "USAID" silo is based on the "Burkino" silo and example of this silo have been erected in Nigeria, holding one tonne of maize grain. A concrete reinforcement slab was made which is 1.5 meters in diameter on which the silo rest. The walls are made of stabilized earth brick and are plastered inside and out with cement reinforced with chicken wire mesh. The top is dome shaped with a central round opening, and covered with a cone-shaped earthen cap. This is plastered with cement, and rest on bamboos or on a metallic drum base. An outlet door, consisting of a 15×30cm plate 1.5mm thick which is smeared with grease for easy sliding, is let into the base concrete slab.

**The ferrocement bin ("ferrumbu")**

This bin is similar to the "Burkino" bin in shape and was developed in Cameroon (Qstergaard, 1977), and tested in a number of African countries. The bin consists mainly of chicken wire plastered inside and out cement mortar.

The wall varies thickness from 3.5cm for a bin of $0.9m^3$ capacity, to 6cm for one of $14.4m^3$ capacity.

**The synthetic silo**

Various attempts have been made to develop small scale storage bins, using synthetic materials such as butyl 1 rubber (O' Dowd, 1971) and high density polyethylene. However, such bins proved to be either too expensive or prone to damage by pests. Also the management level required by such storage facilities is probably too high for most rural situations.

#### 2.4.2.2 The controlled storage bins:

The following are classified as controlled storage bins:

a. Metal silo
b. Wooden silo
c. Concrete or Cement silo
d. Ventilated silo
e. Airtight silo
f. Unsealed silo
g. Flexible sealed silo
h. Plastic/Rubber silo
i. Shallow and Deep silo
j. Underground silo

**The metal silo**

Metallic silos are economically valid for storing large quantities (over 25 tonnes), metal silos are often regarded as too costly for small scale country. Nevertheless, certain projects have been successful in introducing small metal silos of 0.4 to 10 tonne capacity at farm/village level in developing countries like Swaziland (Walker, 1975).

Metal silos are made of smooth or corrugated metal (mainly steel or aluminium), and are cylindrical in shape with a flat metal top and usually but not always, a flat metal bottom. A man-hole with a cover, which may be hinged but is nevertheless lockable, is located, usually to one side, in the top panel; and an outlet pipe provide with a padlock is fitted at the base of the wall. Metallic structures such as silos are known to experience failures and incapability if certain design factors are not met. Therefore, in the design of metallic silos, avoiding silo failures is paramount, therefore if the following is not avoided, it can result in silo failure. These include;

a. Concentration of high loads on comparatively small areas.
b. Poor stability of such high and slender structures endangered by wind action and one sided loading
c. Still dubious knowledge of pressures in storage bins.
d. Lack of experience of many engineers in the planning and analysis of such structures.

**The wooden silo**

Wood is a good material for silo construction because of its low thermal conductivity and low thermal expansion. Wooden products have not been considered for grain silo construction in Nigeria because of the numerous problems which are believed to be associated with timber. Although wood has been successfully used in silo construction in Washington, United State as far back as 1948, which has been favourable compare with silos made of concrete as well as Aluminium (Warner, 1956).

In Nigeria, wood has been primarily used for cribs construction but it is being used for silo construction (Mijinyawa, 1989, Alabadan, 2002).

Advantage of wooden silo

i. It presents a good appearance when properly placed and finished.
ii. It has good ease of workability.
iii. It has low thermal expansion coefficient and low thermal conductivity
iv. The problem of durability and stability in service are surmountable if correct species of wood are chosen and correctly treated.

v. The labour requirement are locally available and inexhaustible if properly planned by tree planting

vi. The raw materials are locally available and inexhaustible of properly planned by tree planting.

Disadvantage of wooden silo

i. Several wood species can rot and many lead to mould growth that will lead to deterioration of the stored grains

ii. Panel joints at different to be made water proof

iii. Difficulty in making the surface of many wood species smooth, cracks and splits may develop, which can lead to insect attract.

iv. Termite attack can cause the wood to go soft and unstable which can lead to collapsing of the structure.

**Concrete/cement silo**

Concrete silos are cementing rich, and often include other materials which normally have to be imported into developing countries. Concrete has been used widely in the construction. Concrete in itself is a durable and economical material for construction. It includes masonry silo, brick silos, hollow tile cement stave and monolithic concrete silo. The use of clay blocks for silo was developed by the Iowa Experimental Station (Iowu silo).

Advantages on concrete silo

i. Large handling is possible

ii. Concrete is fire proof, rodent proof and it can be constructed into any desire shape

iii. The raw materials for concrete silo are locally available and the labour required for the construction is considerably cheap.

iv. The concrete silo is a bad conductor of heat and grain store are protected against moisture condensation.

Disadvantage of concrete silo

i. Concrete is heavy and handling is difficult

ii. Concrete is very poor in tension so the walls must be reinforced to resist the lateral pressure of the grain stored

iii. The difficulty in handling can lead to cracking and breakage of the pre-cast concrete in transit.

iv. Concrete structure are permanent, it can not be easily remoulded.

v. If surface finishes is not smooth, there will be insects attack on the stored grains and this leading to the deterioration of the quality of the grain.

**Ventilated bins/silos**

The ventilated bins or silo may be the most economic system for long-term grain storage especially when the grain can normally be harvested in a fairly dry condition. A ventilated bulk storage system consists essentially of a fan and heater unit to provide a supply of slightly warmer air, ducting to convey the air to the grain and some method of distributing the air so that it passes through the grain in the store. These essential can often be quite cheaply provided, but where large quantities of grain are to be dealt with it becomes desirable to add such, auxiliaries as a damp grains receiving hopper, grain cleaning equipment and conveying equipment to enable easy movement of the grain into and out of the store, or from one part of the system to another. Blowing grain with air of grain of a moisture content of 14 percent, the figure necessary for prolonged storage in bulk without further ventilation the relative humidity of the drying air needs to be about 60-65percent. The mean relative humidity of the atmosphere of the drier parts of Britain over 24hours during harvest time varies from 75 to 85 percent, and continuous ventilation with such atmospheric air will in practice produce grain having moisture of around 17-18 percent. It is necessary to warm the air a little to produce grain of lower moisture content, and the amount of warming needed varies with weather conditions. In cold, wet weather, the average temperature increase needed over the 24 hours to reduce grain to 14 percent M.C is about 6-10$^0$F (3-5.5$^0$C), whereas 0-6$^0$F (0-3$^0$C) temperature rise is adequate to give 6-10$^0$F (3-5.5$^0$C) temperature (Culpin, 1981).

**Airtight silos**

A common method of construction is by use of bolted metal plates protected from corrosion by vitreous enamel or by galvanizing. Provision of pressure relief valves is essential to allow for the expansion contraction of the silo atmosphere owing to ambient temperature changes. The amount of gaseous exchange is highest with empty or nearly empty silos, and this is one of the reasons why deterioration of grain become serious if a little grain is left in a silo in spring or summer. To minimize gaseous exchanges, one manufacturer provides a plastic breather bag. So arranged that on cooling, atmospheric air first enters and inflates the breather bags, and only passes through the relief valve into the main silo air space after the breather bag is full, and the vacuum outside the walls of the bag exceeds the relief value setting. Such devices are useful if grain is to be fed from the silo for an appreciable period during spring and summer. In winter ambient temperature differences are smaller, and the cooler air has fewer tendencies to stimulate microbial activity. (Culpin, 1981).

**Unsealed silos**

The unsealed (tower) silos are mainly used for large stock keeping installation where the moist grain is used up at a rate of at least 3 inch (75mm) of silo height per day and the silo is emptied before the onset of warm weather on spring.

A method that brings about satisfaction is this; to cover the top with at least 6 inch (150mm) of any convenient material to absorb condensation moisture, for example, chopped straw, and to cover this absorbent layer with a heavy gauge polythene sheet, well tricked down at the edges. (Culpin, 1981).

**Flexible sealed silos**

This type of silos may be constructed of butyl rubber or similar flexible material, but good handling systems for filling and employing them are not easily arranged. The silos themselves are relative cheap, and the electricity of the container walls makes it possible to accommodate expansion of the silo atmosphere without the use of relief values. It should, however be reckoned that the trouble free useful life is likely to be much shorter than that of rigid-walled silos (Cuplin, 1981).

**Plastic/rubber silo**

Silos made of plastic/rubber of various types have been tested but found not suitable. Rigid plastics and fibre glass have not been competitive with wood or steel.

Plastic/rubber silo can result into the problem of moisture condensation as a result of high tendency of the material to absorb heat and its high degree of susceptibility rodent attack.

Weathering under the intense heat of this country leaves a lot of cracks graduating into cuts and holes on the silo rubber after a period of use. Losses as much as 60% or more were common in the rubber silo (Agboola, 1985).

**Shallow and deep silo**

Based on various classification methods, silo can either be shallow or deep one of this method is based on the plane or rupture which is determined by repose angle of the stored grain.

A silo is said to be deep when the plane of rupture intersect the silo wall within the grain mass. While a silo is said to be shallow when the plane of rupture do not intersect the silo wall within the grain mass

A silo can also be shallow and deep due to the ratio of height to least lateral dimension. Deep silo is the silo in which the depth is greater than the least lateral dimension while a shallow silo is the silo in which the depth is less than the least lateral dimension.

**Underground silo**

Storage of grain in underground silos is an ancient techniques practiced in many countries. In Morocco, many farmers prefer underground storage for conservation of their produce. It is estimated that storage capacity with this method totals about a million tonnes. This technique, used as well in Tunisia, in Egypt and in Sudan, is adapted to the rural context and to small holdings where soil conditions permits. The atmosphere, poor in oxygen, created inside the underground store, permits a reduction in insect attack. Experiment has shown that insect infestation, fungal growth and taste acceptability are well controlled in underground storage silo system.

## 2.5 Meteorology and Grain Storage

The losses of food grains by damage during storage are often sufficient to wipe out the grains which are made by improved varieties and difficult cultural methods.

And so, meteorology is an important role that must be obeyed in grain storage so that one can understand the extent of damage in order to know the best protective method that can be apply in controlling it.

Much of the damages on grains stored are due to environmental factors on the stored grains. The environmental factors include the temperature, the moisture content of the grains, the relative humidity of the surrounding, the effect of insects, mites and micro-organism and the rodents.

**Temperature:** Temperature is very important factor influencing maize storage. Growth of fungi and chemical changes such as oxidation increased with temperature in both meal and value maize. Insects develop and reproduce best between 27 and 35°C (80-95°F) Below 16°C, insects become inactive and die.

Maize with a moisture content of 11.5-14.5% can be stored one or two years without mould damage while maize stored at a higher moisture content value can be infected by moulds in a few weeks. Recent studies indicate that maize can be stored at 10.5% moisture content at any temperature without the danger of mould attack.

Temperature also influences moisture migration. The driving force in moisture migration in a grain mass is temperature gradient. This condition causes very small air movements and water vapour translocation or the grain mass. It has been estimated that a grain mass temperature gradient of about 16.7°C (30°F) can induce an inter seed air flow of 0.06m/min (0.2ft/min). Thus grains stored at moisture content considered safe, may spoil because of moisture migration associated with inter seed air currents. The air movement in the grain bin is influenced by the outside air temperature that creates temperature gradients in the entire grain mass. This phenomenon affects all types of storage silos whether it is made of concrete or metal. They vary only on the magnitude of air movements.

Because of the insulating property of grains, the effect of diurnal temperature changes on the stored grain is minimal but is cumulative. However, experience indicates that under hot or humid tropical conditions, grains stored in metal bins exhibit 'sweating' next to the wall. This can be attributed to extreme high temperature reached at the inner surface of the metal silo on a hot day. At night rapid cooling of the metal results in moisture condensation as the dew point is reached. Caking and charring in metal silos can be attributed to this phenomenon.

- **Moisture content:** Micro-organism needs a certain level of moisture for good growth. Below this level they will grow very slowly or not even grow at all. Grain produce normally should not be stored with moisture content higher than that which would be equilibrium with relatively humidity Of 70% otherwise, micro-organism will develop and this is referred to as maximum permissible moisture content for safe storage and safe storage for maize is 13.5% (Muckle and Sterling, 1971).

- **Insects and mites:** There are about 30 important storage pests. Development takes place at the temperature between $17^0$C and $35^0$C at almost any moisture content. Mites develop on produce with high moisture content while pests develop completely inside the cereals. Some pests could also be found to develop outside the produce.

- **Micro-organisms**: Development of most species takes place between $5^0$C and $30^0$C some however has their optimum growth at $50^0$C – $60^0$C while other still develop below $5^0$C.

**Rodents:** In general, rodents cause greater damage to the standing crop than the crop in storage. Losses are caused by direct consumption by the rodents.

## 2.6 Quality Characteristics of Grain

The certain criteria of grain qualities established in any grading standard are those that are of most importance for the end-use. Generally, these criteria, according FAO (1994), are the intrinsic varietal qualities and those that are environment or process-induced.

The intrinsic qualities assigned to grains include composition, colour, bulk density, odour and aroma as well as size and shape; induced qualities are age, broken grain, chalky or immature grain, foreign matter, infested and infected grains and moisture content.

On the other hand, Henderson and Perry (1980) classified the quality criteria, which they termed as grade factors, under three broad headings of; physical characteristics include moisture content until size and weight, texture, colour, foreign matter and shape; chemical characteristics include such factors as viability, type and amount of insect damage, and amount of mould damage.

All of these characteristics and how they influence grain quality are described in the following sections.

### 2.6.1 The intrinsic qualities

#### 2.6.1.1 Composition

Grains are known to be made up of organic and dry mater. The grains organic matter is made up of carbohydrates, lipid, protein and vitamins while the dry matter of grain consists of mineral matter (ash) and organic matter. The function of carbohydrate is to provide energy for use by the body. Fats and lipids also provide energy, but they are being oxidized into fatty acids when the conditions of storage are bad. They develop a rancid odour and flavour in the grain as a result of this. Vitamins found in mixture quantities in cereal grains are essential for body functions. These vitamins found in mixture quantities in cereal grains are essential for body functions. These vitamins can be destroyed by excessive heat or insect activities during storage certain changes to lipids in grains and carbohydrate are on the other hand desirable

Other components of grain such as husk in maize are not inedible and according to FAO (1994) quantitatively influence product yield and gross nutrient available to the consumer.

#### 2.6.1.2 Grain colour

Cereal grains are pigmented and range through the colour spectrum from very light tan or almost white, to black. Where extractive milling is required, highly pigmented varieties may give low yields better white flour (Codex Alimentaries Commission).

#### 2.6.1.3 Aroma/Odour

Fresh grains are normally known to have national aroma or odours that are distinctive. A grain is considered bad when the odour of the grain differs from the accepted characteristics one grains odour or aroma indicates grain quality.

### 2.6.2 Induced qualities of grains

#### 2.6.2.1 Contaminants

The traces of chemical left on the grains for insect control constitutes the contaminants. These residues often taint the grain or in some rare cases add toxic residues to the maize grains. Tainted grain is obviously of low quality.

#### 2.6.2.2 Chalky or immature grains

Immature grains came about as a result of lack of starchy endosperm found in them at harvest. This condition is as a result of sterility, filed infections, insect attack and so on. Immature grain content is influenced by time of harvest, a high content of this being the result of too early harvest. FAO (1994) give the cause for grain chalkiness as incomplete filling of the starchy endosperm. From observation, to is be revealed that immaturity of grain lower the mechanical strength of the grain and causes it to break easily during handling. The broken grain portion is of course, more easily invaded by certain storage pests.

#### 2.6.2.3 Infected and infested grain

Infested grains or grains that are damaged by micro-organism are said to be inferior quality. Insect damage to grain has been grouped into categories (Grey, 1966) Viz;

(i) Bored holes and the disappearance of a large portion of the inside of the kernels;

(ii) Injury to the germs;

(iii) Heating and consequent condensation and moulding of the grain mass and

(iv) Contamination with excrements and webbing.

The first category of damage results in loss of weight and food yield. Injury to the germs reduces the grain ability to germinate. Contamination has a direct implication on food hygiene.

On the other hand, the preserve of micro organisms may result in spoilage and in certain instance when toxins produced are ingested health problems do occur.

## 2.7 Grain quality standards

A standard is a precise and authoritative statement of the criteria/specification necessary to ensure that a material, product of procedure is fit for the purpose for which it is intended. It therefore helps to define products and lay down quality assurance producers for ensuring that the quality is in harmony with the generally established standards (SON, 1989). Standards are established for a very wide variety of materials, products and services. Quality standards are established for grains in order to provide an unambiguous description of their quality, to protect consumer's rights and to provide a clear indication of quality requirement to both producer and end-user.

Quality standards for grains are also known as grading standards because grading itself means sorting the grain into its various quality fractions under a standard classification on the basis of commercial value or usage. The establishment of these grading standards will therefore set the guidelines and rules for sale and purchase of grains. However in Nigeria, these standards are rarely employed in grain marketing. One of the reasons for this is that grain trade involves direct choice and price negotiation by the buyer, in front of the commodity. In such a situation the quantity of the grain will be assessed visually and it will be influenced by the end use. The price will also be determined by local factors. Another reason for non-compliance with standards is that most buying and selling of grain back place in rural areas and standard. Grain standards are nevertheless established and implemented in flour mill and government storage depots.

Grain quality standards are of three types Viz; standard specification, standard test method and grading standards. Standard specifications basically define and specify the grain. They provide criteria for characterizing the nature of the grain, usually on a pass or fail basis. A

sample of grain is judged against the standard and may be accepted if it passes all the criteria listed.

Standard test method sets down the producers for testing the specifications of grain samples. All samples must be tested in accordance with the standard methods before the results can be accepted as truly representing the quality of grain being considered. Grading standards are used to group (grade) grain into one of several classes based on inherent quality and projected market value.

# CHAPTER THREE

## 3.0 METHODOLOGY

### 3.1 Project Location

The project is being carried out at the Federal University of Technology, Minna, Niger state.

It is necessary to consider the temperature, relative humidity and rainfall of the environment where the silo is being used for these factors will influence the quality of the stored grains and material (metal) used in the construction of the silo is being considered for use under the warm humid climate of Niger State. A five years record (2005-2009) of rainfall, temperature, and relative humidity for this location are presented in table 3.1 (see appendix).

#### 3.1.1Temperature

From the tables we can also observe that the temperature is lowest between July and August. The temperature then begins to increase almost steadily from August till March and decreases steadily from the month of April.

#### 3.1.2 Relative humidity

From the tables it is observed that the relative humidity is higher for the wet months (April-October) than the dry months (November-March). Storage period therefore coincide with of high relative humidity.

#### 3.1.3 Rainfall

From the tables, we can also see that there are two seasons, the wet and dry season. The wet season lasts from April-October, while the dry season lasts from November-March. It is observed from the tables that the maximum rainfall was between the months of July-September.

### 3.2 Initial Condition of the Grains

#### 3.2.1 Moisture content

In stored grains changes occur in the fat acidity, colour, vitamins, e.t.c. These changes are influenced greatly by the moisture content and temperature which are often used as a means of indicating the quality of the stored products.

The initial moisture content of the grains was determined using the grain moisture meter probe and measured at 12.6%

#### 3.2.2 Colour

There is the need to determine the initial colour of the grains before storage; this is done in order to be able to determine if there is any change in colour during the storage period. The initial colour of the grains was noted to be mild milk colour with visual view.

#### 3.2.3 Infestation

The source of infestation for the stored commodity may be from the field crop itself which is carried along with the grain. The detection of this infestation is a must for safe storage. Before storage, the grains were properly checked with visual view to make sure that they were not infested from the market.

### 3.3 Initial Condition of the Silo

#### 3.3.1Size

The silo was designed to a capacity of 1 metric tone for shelled corn.

### 3.3.2 Shape

The metal silo is cylindrical in shape with an inner diameter of…

### 3.3.3 Materials

The material used in the construction of the metal silo is steel.

## 3.4 Silo Evaluation

### 3.4.1 Effect of weather on silo

**Peeling**

A daily observation revealed that there are no changes that occurred on the body of the metal silo.

**Colour**

A daily observation on the silo also showed that there is no colour change around the body of the silo.

## 3.5 Grains Evaluation

### 3.5.1 Temperature

It was considered necessary to monitor the variation of temperature within and outside the silo since comparison between the ambient temperature and that within the silo provides information on the rate of heat movement into and out of the structure. The relative humidity and temperature meter were used to read the temperature, ambient temperature and relative humidity respectively, from the top, middle and bottom of the metal silo and the corresponding results were recorded.

### 3.5.2 Infestation

The application of coopex dust and phostoxine tablet at the point of storage, prevent the problem physical damage caused by insect.

### 3.5.3 Moisture content

The moisture content of the grains within the silo structure is an indication of the amount of moisture present.

Moisture content measurement is very necessary because it provides a fairly reliable estimate of grains suitability for safe and even during storage.

The measurement of moisture content of the grain was done using moisture meter probe. The readings were taken once in a week, three times a day for a period of 12 weeks.

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 RESULTS

Tables 4.1 (see appendix) show a daily record of the temperature and relative humidity of grains. Two temperatures reading were taken; the ambient temperature of the silo environment and temperature of the maize were taken in the morning, afternoon and evening.

### 4.2 DISCUSSION

#### 4.2.1 Temperature Changes

**Silo temperature**

Figure 1a to figure 1c (see appendix) is the graph of the silo (room temperature) recorded from the month of August to October showing the average daily temperature changes.

From the graph it was observed that the temperature within the silo was at the highest in the month of August and lowest in the month of September. This is as a result of low rainfall around ending of July to August ending and higher rainfall in mid September to the end of the same month.

**Ambient temperature**

Figure 2 is the graph of the ambient temperatures recorded from the month of august to October shows a typical daily temperature variation for morning, afternoon and evening periods.

From figure 2(a) - 2(d), it was observed that the ambient temperature recorded for each month of the storage period can be compared to the silo temperature recorded for the same

**Climatic Data for 2007**

| MONTH | TEMPERATURE °C | RAINFALL mm | RELATIVE HUMIDITY (%) |
|---|---|---|---|
| JANUARY | 33.7 | 0.0 | 22.0 |
| FEBUARY | 37.2 | 0.0 | 30.0 |
| MARCH | 38.2 | 0.4 | 41.0 |
| APRIL | 36.0 | 73.1 | 64.0 |
| MAY | 32.8 | 156.6 | 76.0 |
| JUNE | 30.3 | 123.9 | 80.0 |
| JULY | 29.5 | 314.0 | 85.0 |
| AUGUST | 28.2 | 310.1 | 88.0 |
| SEPTEMBER | 30.0 | 330.2 | 83.0 |
| OCTOBER | 31.7 | 115.1 | 77.0 |
| NOVEMBER | 34.7 | 0.0 | 56.0 |
| DECEMBER | 35.4 | 0.0 | 33.0 |

Nigerian Meteorological Centre, Minna

**Table 4.1: Daily Temperature Readings of Grains**

**August**

| Date | Time | Temperature | | | | Relative Humidity (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | Room Temperature | | | Ambient Temperature | | | |
| | | Top | Middle | Bottom | | Top | Middle | Bottom |
| | morning | 27.4 | 27.6 | 27.3 | 30.9 | 72.2 | 72.2 | 75.0 |
| Aug.1 | afternoon | 28.3 | 28.5 | 28.6 | 31.1 | 66.5 | 75.1 | 75.0 |
| | evening | 28.0 | 28.2 | 28.4 | 34.1 | 87.0 | 91.0 | 90.0 |
| | | | | | | | | |
| | morning | 29.0 | 30.6 | 27.9 | 29.5 | 63.7 | 74.6 | 66.5 |
| Aug.2 | afternoon | 29.6 | 30.9 | 29.9 | 30.1 | 83.0 | 88.1 | 80.0 |
| | evening | 29.3 | 29.8 | 29.1 | 29.9 | 90.0 | 86.9 | 91.0 |
| | | | | | | | | |
| | morning | 27.5 | 28.2 | 27.7 | 26.6 | 81.8 | 75.4 | 66.8 |
| Aug.3 | afternoon | 29.1 | 29.9 | 28.9 | 26.9 | 72.2 | 81.0 | 83.2 |
| | evening | 28.0 | 28.4 | 28.1 | 26.8 | 80.1 | 75.7 | 74.3 |
| | | | | | | | | |
| | morning | 25.5 | 26.8 | 26.1 | 26.0 | 73.9 | 73.8 | 71.6 |
| Aug.4 | afternoon | 26.9 | 27.3 | 27.4 | 27.8 | 69.1 | 77.8 | 72.7 |
| | evening | 25.8 | 26.9 | 27.1 | 27.0 | 82.0 | 94.0 | 96.5 |
| | | | | | | | | |
| | morning | 27.1 | 27.8 | 27.9 | 28.8 | 77.9 | 92.0 | 90.0 |
| Aug.5 | afternoon | 27.9 | 28.2 | 28.6 | 29.1 | 66.5 | 77.5 | 85.1 |
| | evening | 27.4 | 28.0 | 28.3 | 29.0 | 88.0 | 92.0 | 74.0 |
| | | | | | | | | |
| | morning | 25.5 | 25.7 | 25.6 | 23.2 | 74.0 | 73.5 | 96.0 |
| Aug.6 | afternoon | 25.8 | 25.8 | 25.8 | 24.0 | 69.6 | 87.7 | 78.4 |
| | evening | 25.7 | 25.6 | 25.6 | 23.1 | 76.0 | 66.4 | 71.6 |
| | | | | | | | | |
| | morning | 26.2 | 25.9 | 26.5 | 27.7 | 68.5 | 65.6 | 73.3 |
| Aug.7 | afternoon | 28.0 | 27.7 | 27.5 | 29.7 | 67.5 | 66.7 | 66.5 |
| | evening | 27.8 | 27.1 | 26.9 | 30.1 | 70.0 | 72.7 | 90.0 |
| | | | | | | | | |
| | morning | 27.0 | 27.9 | 27.1 | 26.9 | 67.7 | 90.5 | 87.6 |
| Aug.8 | afternoon | 27.6 | 27.3 | 26.7 | 27.9 | 73.4 | 77.5 | 76.1 |
| | evening | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 76.4 |
| | | | | | | | | |
| | morning | 26.8 | 26.6 | 25.9 | 25.4 | 70.6 | 86.0 | 89.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Aug.9** | **afternoon** | 27.1 | 26.9 | 26.1 | 25.6 | 76.4 | 73.5 | 83.4 |
| | **evening** | 26.9 | 26.8 | 25.8 | 25.2 | 93.0 | 92.0 | 86.1 |
| | **morning** | 26.1 | 26.3 | 26.0 | 26.5 | 79.1 | 73.5 | 90.0 |
| **Aug.10** | **afternoon** | 27.9 | 27.8 | 28.7 | 27.8 | 63.6 | 69.4 | 67.6 |
| | **evening** | 26.8 | 27.6 | 27.5 | 27.2 | 70.1 | 72.4 | 75.4 |
| | **morning** | 27.7 | 27.6 | 27.9 | 26.9 | 85.0 | 78.5 | 92.0 |
| **Aug.11** | **afternoon** | 28.0 | 28.1 | 27.8 | 28.8 | 69.2 | 67.5 | 68.7 |
| | **evening** | 28.1 | 27.7 | 27.5 | 27.3 | 75.7 | 72.5 | 75.9 |
| | **morning** | 28.2 | 28.3 | 28.0 | 27.4 | 66.4 | 68.5 | 70.7 |
| **Aug.12** | **afternoon** | 29.6 | 29.0 | 29.4 | 29.7 | 65.6 | 65.4 | 68.4 |
| | **evening** | 29.3 | 29.1 | 28.9 | 28.8 | 71.0 | 67.1 | 66.4 |
| | **morning** | 26.2 | 25.9 | 26.5 | 27.7 | 68.5 | 65.6 | 73.3 |
| **Aug.13** | **afternoon** | 28.0 | 27.7 | 27.5 | 29.7 | 67.5 | 66.7 | 65.5 |
| | **evening** | 27.8 | 27.1 | 26.9 | 30.1 | 73.3 | 70.8 | 63.7 |
| | **morning** | 27.0 | 27.9 | 27.1 | 26.9 | 67.7 | 90.5 | 88.6 |
| **Aug.14** | **afternoon** | 27.6 | 27.3 | 26.7 | 27.9 | 73.4 | 77.5 | 76.1 |
| | **evening** | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 76.4 |
| | **morning** | 26.1 | 26.3 | 26.0 | 26.5 | 89.1 | 78.2 | 86.0 |
| **Aug.15** | **afternoon** | 27.9 | 27.8 | 28.7 | 27.8 | 63.6 | 69.4 | 67.6 |
| | **evening** | 26.8 | 27.6 | 27.5 | 27.2 | 70.1 | 72.4 | 75.4 |
| | **morning** | 27.1 | 26.8 | 26.1 | 28.0 | 69.6 | 63.0 | 68.0 |
| **Aug.16** | **afternoon** | 28.0 | 28.1 | 27.8 | 28.8 | 69.2 | 67.5 | 68.7 |
| | **evening** | 23.2 | 23.3 | 28.0 | 27.4 | 66.4 | 68.5 | 70.7 |
| | **morning** | 29.6 | 29.0 | 29.4 | 29.7 | 65.6 | 65.4 | 65.8 |
| **Aug.17** | **afternoon** | 30.1 | 29.5 | 29.3 | 31.0 | 79.8 | 71.3 | 78.0 |
| | **evening** | 29.9 | 29.3 | 29.0 | 30.6 | 96.0 | 73.3 | 75.3 |
| | **morning** | 29.8 | 29.6 | 28.4 | 28.0 | 68.7 | 70.8 | 72.5 |
| **Aug.18** | **afternoon** | 29.9 | 29.8 | 28.9 | 32.0 | 67.0 | 66.7 | 70.3 |
| | **evening** | 27.9 | 27.8 | 28.7 | 27.8 | 63.6 | 69.4 | 67.6 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Aug.19** | **morning** | 26.6 | 26.5 | 26.9 | 26.3 | 67.7 | 69.7 | 71.8 |
| | **afternoon** | 29.6 | 28.8 | 29.4 | 29.7 | 66.0 | 68.8 | 65.8 |
| | **evening** | 27.3 | 26.9 | 27.1 | 27.2 | 69.4 | 76.2 | 69.8 |
| | | | | | | | | |
| **Aug.20** | **morning** | 28.8 | 28.2 | 28.4 | 29.2 | 66.6 | 72.3 | 68.4 |
| | **afternoon** | 27.6 | 27.9 | 27.7 | 27.7 | 70.6 | 74.7 | 75.9 |
| | **evening** | 27.3 | 26.9 | 27.1 | 27.2 | 69.4 | 76,2 | 68.8 |
| | | | | | | | | |
| **Aug.21** | **morning** | 25.7 | 25.5 | 25.2 | 25.4 | 77.7 | 79.1 | 78.8 |
| | **afternoon** | 27.8 | 28.4 | 28.0 | 27.7 | 70.3 | 75.0 | 70.3 |
| | **evening** | 27.1 | 27.8 | 28.1 | 27.7 | 73.8 | 72.3 | 73.2 |
| | | | | | | | | |
| **Aug.22** | **morning** | 26.6 | 27.2 | 27.1 | 27.1 | 71.9 | 79.1 | 82.1 |
| | **afternoon** | 27.4 | 27.7 | 27.6 | 27.4 | 66.9 | 71.5 | 83.7 |
| | **evening** | 25.9 | 25.2 | 26.1 | 27.2 | 65.9 | 78.9 | 73.4 |
| | | | | | | | | |
| **Aug.23** | **morning** | 29.6 | 29.7 | 29.1 | 30.2 | 64.6 | 63.2 | 65.7 |
| | **afternoon** | 30.1 | 30.3 | 29.3 | 32.0 | 86.1 | 78.9 | 66.4 |
| | **evening** | 26.9 | 26.7 | 26.0 | 28.0 | 67.0 | 71.1 | 69.9 |
| | | | | | | | | |
| **Aug.24** | **morning** | 26.7 | 27.7 | 27.2 | 26.7 | 66.5 | 81.6 | 79.8 |
| | **afternoon** | 30.6 | 28.6 | 27.7 | 32.0 | 57.5 | 66.6 | 69.6 |
| | **evening** | 28.2 | 28.3 | 28.2 | 28.5 | 67.7 | 68.3 | 68.8 |
| | | | | | | | | |
| **Aug.25** | **morning** | 27.4 | 27.4 | 27.1 | 27.4 | 69.9 | 76.0 | 74.5 |
| | **afternoon** | 28.5 | 29.2 | 28.2 | 29.6 | 69.6 | 69.1 | 68.2 |
| | **evening** | 28.1 | 27.6 | 27.9 | 28.0 | 67.1 | 73.2 | 79.8 |
| | | | | | | | | |
| **Aug.26** | **morning** | 26.0 | 26.8 | 26.7 | 26.9 | 66.6 | 70.4 | 73.7 |
| | **afternoon** | 26.1 | 26.5 | 25.0 | 27.0 | 83.0 | 63.0 | 66.1 |
| | **evening** | 25.2 | 25.8 | 25.0 | 26.8 | 74.5 | 73.6 | 76.1 |
| | | | | | | | | |
| **Aug.27** | **morning** | 26.8 | 25.0 | 26.1 | 27.1 | 77.2 | 84.0 | 76.0 |
| | **afternoon** | 28.8 | 25.8 | 27.8 | 26.1 | 66.5 | 69.3 | 68.1 |
| | **evening** | 29.8 | 30.5 | 30.0 | 30.4 | 63.8 | 67.1 | 59.9 |
| | | | | | | | | |
| **Aug.28** | **morning** | 28.4 | 27.8 | 27.3 | 28.0 | 56.5 | 61.9 | 66.3 |
| | **afternoon** | 29.5 | 28.0 | 27.6 | 29.9 | 58.7 | 64.5 | 68.4 |
| | **evening** | 25.6 | 26.8 | 26.7 | 26.5 | 59.8 | 64.3 | 61.7 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Aug.29** | **morning** | 25.0 | 25.4 | 25.5 | 24.9 | 93.0 | 77.9 | 88.1 |
| | **afternoon** | 27.6 | 27.4 | 26.9 | 29.0 | 64.5 | 66.7 | 65.4 |
| | **evening** | 28.1 | 28.1 | 28.0 | 28.3 | 68.6 | 82.0 | 70.9 |
| | | | | | | | | |
| **Aug.30** | **morning** | 25.5 | 26.0 | 26.3 | 26.0 | 77.0 | 86.0 | 83.3 |
| | **afternoon** | 29.9 | 27.7 | 29.1 | 28.8 | 68.0 | 66.7 | 81.4 |
| | **evening** | 31.4 | 28.9 | 30.1 | 29.2 | 65.0 | 54.3 | 71.2 |
| | | | | | | | | |
| **Aug.31** | **morning** | 25.0 | 25.0 | 24.9 | 24.8 | 92.0 | 89.6 | 71.5 |
| | **afternoon** | 28.2 | 26.6 | 27.5 | 26.2 | 88.0 | 76.3 | 79.8 |
| | **evening** | 27.9 | 25.5 | 29.0 | 28.8 | 76.0 | 69.1 | 67.1 |
| | | | | | | | | |

**Table 4.1: Daily Temperature Readings of Grains**

**September**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sep.1 | morning | 26.4 | 26.3 | 26.5 | 27.5 | 69.6 | 76.4 | 72.0 |
| | afternoon | 26.4 | 26.5 | 26.0 | 27.0 | 74.9 | 85.9 | 79.3 |
| | evening | 27.7 | 27.9 | 27.8 | 27.7 | 68.1 | 72.0 | 71.8 |
| | | | | | | | | |
| Sep.2 | morning | 25.9 | 26.3 | 26.2 | 26.1 | 68.4 | 83.2 | 77.9 |
| | afternoon | 26.5 | 26.8 | 26.4 | 27.0 | 67.0 | 76.6 | 78.6 |
| | evening | 29.1 | 27.2 | 27.2 | 29.9 | 63.0 | 70.9 | 76.8 |
| | | | | | | | | |
| Sep.3 | morning | 27.8 | 26.9 | 26.0 | 65.6 | 73.5 | 69.0 | 74.0 |
| | afternoon | 28.0 | 27.3 | 26.9 | 28.1 | 63.3 | 70.1 | 71.1 |
| | evening | 28.1 | 28.0 | 27.9 | 28.0 | 67.0 | 69.9 | 71.0 |
| | | | | | | | | |
| 4-Sep | morning | 26.6 | 26.7 | 26.3 | 26.9 | 67.2 | 77.0 | 78.3 |
| | afternoon | 30.5 | 27.7 | 28.0 | 30.8 | 61.6 | 70.8 | 74.5 |
| | evening | 28.8 | 28.7 | 28.4 | 28.6 | 66.4 | 75.0 | 72.0 |
| | | | | | | | | |
| 5-Sep | morning | 26.6 | 26.5 | 26.0 | 26.5 | 67.8 | 76.0 | 77.7 |
| | afternoon | 27.5 | 26.8 | 26.6 | 27.6 | 65.1 | 71.1 | 72.7 |
| | evening | 27.1 | 27.1 | 27.2 | 26.9 | 68.6 | 76.5 | 79.1 |
| | | | | | | | | |
| 6-Sep | morning | 26.5 | 27.9 | 28.1 | 28.3 | 73.2 | 76.1 | 75.4 |
| | afternoon | 27.4 | 27.5 | 27.7 | 27.4 | 65.2 | 72.9 | 69.8 |
| | evening | 28.8 | 28.0 | 28.0 | 28.3 | 70.0 | 70.3 | 68.3 |
| | | | | | | | | |
| 7-Sep | morning | 28.2 | 27.9 | 28.0 | 27.0 | 65.2 | 62.4 | 78.1 |
| | afternoon | 27.3 | 29.0 | 28.3 | 28.8 | 77.7 | 81.9 | 69.9 |
| | evening | 27.7 | 27.5 | 28.0 | 27.3 | 69.0 | 76.1 | 81.3 |
| | | | | | | | | |
| 8-Sep | morning | 26.4 | 27.7 | 26.0 | 27.0 | 76.9 | 83.1 | 87.0 |
| | afternoon | 26.6 | 26.2 | 26.2 | 27.3 | 70.1 | 75.1 | 81.2 |
| | evening | 27.0 | 27.1 | 27.2 | 27.5 | 66.1 | 74.9 | 78.8 |
| | | | | | | | | |
| 9-Sep | morning | 27.8 | 28.2 | 28.9 | 27.0 | 65.8 | 73.1 | 64.0 |
| | afternoon | 26.6 | 26.8 | 27.3 | 27.2 | 66.8 | 80.3 | 82.9 |
| | evening | 27.7 | 27.1 | 26.9 | 27.0 | 79.6 | 81.3 | 80.7 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **10-Sep** | **morning** | 26.8 | 26.9 | 27.1 | 27.3 | 68.0 | 74.9 | 83.9 |
| | **afternoon** | 27.1 | 27.4 | 27.5 | 27.4 | 66.5 | 74.0 | 82.6 |
| | **evening** | 28.6 | 27.0 | 28.3 | 28.8 | 87.0 | 89.0 | 97.0 |
| | | | | | | | | |
| **11-Sep** | **morning** | 26.9 | 27.3 | 27.4 | 27.8 | 69.1 | 77.8 | 72.7 |
| | **afternoon** | 27.9 | 27.8 | 28.7 | 27.8 | 70.1 | 72.4 | 75.4 |
| | **evening** | 26.8 | 27.6 | 27.5 | 27.2 | 81.8 | 75.4 | 66.8 |
| | | | | | | | | |
| **12-Sep** | **morning** | 25.9 | 25.2 | 26.1 | 27.2 | 65.9 | 78.9 | 73.4 |
| | **afternoon** | 27.5 | 28.2 | 27.7 | 26.6 | 81.8 | 75.4 | 66.8 |
| | **evening** | 29.0 | 29.9 | 27.9 | 29.0 | 63.7 | 79.0 | 66.5 |
| | | | | | | | | |
| **13-Sep** | **morning** | 27.0 | 27.9 | 27.1 | 26.9 | 67.7 | 90.5 | 88.6 |
| | **afternoon** | 27.6 | 27.3 | 26.7 | 27.9 | 73.4 | 77.5 | 76.1 |
| | **evening** | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 76.4 |
| | | | | | | | | |
| **14-Sep** | **morning** | 29.6 | 29.7 | 29.1 | 30.2 | 64.6 | 63.2 | 65.7 |
| | **afternoon** | 30.1 | 30.3 | 29.3 | 32.0 | 86.1 | 78.9 | 66.4 |
| | **evening** | 26.9 | 26.7 | 26.0 | 28.0 | 67.0 | 71.1 | 69.9 |
| | | | | | | | | |
| **15-Sep** | **morning** | 26.8 | 26.7 | 26.3 | 26.3 | 70.2 | 72.7 | 73.2 |
| | **afternoon** | 27.2 | 27.1 | 26.9 | 27.0 | 66.2 | 70.1 | 72.0 |
| | **evening** | 26.7 | 26.9 | 26.5 | 26.4 | 69.7 | 73.3 | 72.5 |
| | | | | | | | | |
| **16-Sep** | **morning** | 26.3 | 26.2 | 26.4 | 26.9 | 63.4 | 70.3 | 82.1 |
| | **afternoon** | 28.6 | 27.7 | 27.4 | 28.7 | 62.2 | 67.0 | 70.4 |
| | **evening** | 28.5 | 27.5 | 27.2 | 28.6 | 61.9 | 67.0 | 70.2 |
| | | | | | | | | |
| **17-Sep** | **morning** | 28.0 | 28.1 | 27.8 | 28.8 | 69.2 | 67.5 | 68.7 |
| | **afternoon** | 28.0 | 27.8 | 27.5 | 28.2 | 61.0 | 66.5 | 70.6 |
| | **evening** | 27.9 | 28.2 | 28.6 | 29.1 | 66.5 | 77.5 | 85.1 |
| | | | | | | | | |
| **18-Sep** | **morning** | 27.6 | 27.3 | 26.7 | 27.0 | 73.4 | 77.5 | 76.1 |
| | **afternoon** | 27.4 | 27.7 | 27.6 | 28.0 | 67.1 | 74.9 | 80.9 |
| | **evening** | 27.3 | 27.4 | 27.7 | 27.9 | 68.6 | 73.7 | 77.4 |
| | | | | | | | | |
| **19-Sep** | **morning** | 26.3 | 26.3 | 26.4 | 26.4 | 65.4 | 72.2 | 82.2 |
| | **afternoon** | 27.1 | 27.8 | 27.9 | 28.8 | 76.1 | 89.0 | 79.8 |
| | **evening** | 27.0 | 27.2 | 27.5 | 27.6 | 66.5 | 73.3 | 77.1 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **20-Sep** | **morning** | 26.5 | 26.6 | 26.9 | 27.1 | 64.5 | 70.3 | 81.5 |
| | **afternoon** | 27.7 | 28.0 | 28.2 | 66.5 | 70.1 | 76.5 | 73.0 |
| | **evening** | 29.9 | 29.3 | 28.9 | 31.0 | 67.0 | 69.0 | 70.3 |
| | | | | | | | | |
| **21-Sep** | **morning** | 26.6 | 27.6 | 27.5 | 27.0 | 70.1 | 79.0 | 75.4 |
| | **afternoon** | 28.0 | 28.5 | 28.6 | 28.9 | 68.3 | 76.7 | 70.7 |
| | **evening** | 28.8 | 29.1 | 29.0 | 29.2 | 66.7 | 71.2 | 77.8 |
| | | | | | | | | |
| **22-Sep** | **morning** | 26.2 | 25.5 | 26.5 | 28.0 | 68.4 | 65.6 | 73.2 |
| | **afternoon** | 28.0 | 27.8 | 27.5 | 29.6 | 67.5 | 66.6 | 66.5 |
| | **evening** | 27.7 | 27.1 | 26.9 | 30.1 | 98.0 | 92.7 | 83.0 |
| | | | | | | | | |
| **23-Sep** | **morning** | 27.0 | 27.4 | 27.5 | 27.7 | 66.5 | 70.3 | 73.1 |
| | **afternoon** | 28.8 | 26.1 | 27.8 | 28.0 | 66.5 | 87.0 | 87.4 |
| | **evening** | 29.0 | 30.5 | 31.1 | 30.4 | 63.8 | 67.1 | 65.0 |
| | | | | | | | | |
| **24-Sep** | **morning** | 27.6 | 27.4 | 26.9 | 29.0 | 64.5 | 66.7 | 65.4 |
| | **afternoon** | 27.4 | 27.7 | 27.7 | 27.9 | 66.0 | 70.3 | 77.4 |
| | **evening** | 26.0 | 26.6 | 25.9 | 26.1 | 81.0 | 79.3 | 67.0 |
| | | | | | | | | |
| **25-Sep** | **morning** | 27.0 | 26.9 | 27.1 | 26.8 | 67.7 | 83.0 | 88.6 |
| | **afternoon** | 28.0 | 27.3 | 26.8 | 29.0 | 73.4 | 74.0 | 76.1 |
| | **evening** | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 77.0 |
| | | | | | | | | |
| **26-Sep** | **morning** | 26.3 | 26.3 | 26.3 | 26.3 | 63.4 | 71.9 | 73.8 |
| | **afternoon** | 28.5 | 29.2 | 28.2 | 29.6 | 69.6 | 69.1 | 68.2 |
| | **evening** | 26.8 | 25.8 | 27.8 | 26.0 | 66.5 | 67.0 | 68.1 |
| | | | | | | | | |
| **27-Sep** | **morning** | 26.6 | 26.6 | 26.3 | 26.8 | 98.0 | 96.0 | 83.3 |
| | **afternoon** | 27.6 | 27.5 | 27.2 | 27.9 | 66.9 | 68.0 | 78.0 |
| | **evening** | 24.7 | 24.9 | 25.0 | 24.8 | 93.0 | 84.4 | 92.9 |
| | | | | | | | | |
| **28-Sep** | **morning** | 27.2 | 27.9 | 27.7 | 27.7 | 70.6 | 86.0 | 75.9 |
| | **afternoon** | 27.3 | 26.0 | 27.1 | 27.2 | 70.0 | 76.2 | 68.8 |
| | **evening** | 27.7 | 27.9 | 27.8 | 28.0 | 68.6 | 80.9 | 81.5 |
| | | | | | | | | |
| **29-Sep** | **morning** | 25.5 | 26.0 | 26.3 | 26.0 | 77.0 | 86.0 | 83.3 |
| | **afternoon** | 29.9 | 27.7 | 29.1 | 28.8 | 68.0 | 66.7 | 81.4 |
| | **evening** | 31.4 | 28.9 | 30.1 | 29.2 | 65.0 | 54.3 | 71.2 |
| | | | | | | | | |
| **30-Sep** | **morning** | 26.6 | 26.7 | 26.3 | 26.9 | 67.2 | 77.0 | 78.3 |
| | **afternoon** | 30.5 | 27.7 | 28.0 | 30.8 | 61.6 | 70.8 | 74.5 |
| | **evening** | 28.8 | 28.7 | 28.4 | 28.6 | 66.4 | 75.0 | 72.0 |
| | | | | | | | | |

**Table 4.1: Daily Temperature Readings of Grains**

<u>**October**</u>

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | morning | 26.0 | 27.3 | 27.0 | 26.5 | 88.0 | 92.0 | 74.4 |
| 1-Oct | afternoon | 28.3 | 28.7 | 28.6 | 28.8 | 66.0 | 78.7 | 82.1 |
| | evening | 29.4 | 29.0 | 28.2 | 29.0 | 78.0 | 66.0 | 71.9 |
| | | | | | | | | |
| | morning | 27.8 | 26.9 | 26.0 | 65.6 | 73.5 | 69.0 | 74.0 |
| 2-Oct | afternoon | 28.0 | 27.3 | 26.9 | 28.1 | 63.3 | 70.1 | 71.1 |
| | evening | 28.1 | 28.0 | 27.9 | 28.0 | 67.0 | 69.9 | 71.0 |
| | | | | | | | | |
| | morning | 25.0 | 25.0 | 24.9 | 24.8 | 92.0 | 89.6 | 71.5 |
| 3-Oct | afternoon | 28.2 | 26.6 | 27.5 | 26.2 | 88.0 | 76.3 | 79.8 |
| | evening | 27.9 | 25.5 | 29.0 | 28.8 | 76.0 | 69.1 | 67.1 |
| | | | | | | | | |
| | morning | 26.1 | 26.2 | 26.3 | 26.8 | 72.7 | 75.9 | 76.1 |
| 4-Oct | afternoon | 26.0 | 28.0 | 27.1 | 25.6 | 86.6 | 82.8 | 70.9 |
| | evening | 25.0 | 26.1 | 25.3 | 24.9 | 77.7 | 69.4 | 80.0 |
| | | | | | | | | |
| | morning | 28.0 | 27.8 | 27.5 | 28.2 | 61.0 | 66.5 | 70.6 |
| 5-Oct | afternoon | 27.9 | 28.2 | 28.6 | 29.1 | 66.5 | 77.5 | 85.1 |
| | evening | 28.1 | 28.5 | 28.6 | 27.0 | 66.3 | 69.9 | 75.0 |
| | | | | | | | | |
| | morning | 26.4 | 26.3 | 26.5 | 27.5 | 69.6 | 76.4 | 72.0 |
| 6-Oct | afternoon | 26.4 | 26.5 | 26.0 | 27.0 | 74.9 | 85.9 | 79.3 |
| | evening | 27.7 | 27.9 | 27.8 | 27.7 | 68.1 | 72.0 | 71.8 |
| | | | | | | | | |
| | morning | 25.9 | 26.3 | 26.2 | 26.1 | 68.4 | 83.2 | 77.9 |
| 7-Oct | afternoon | 26.5 | 26.8 | 26.4 | 27.0 | 67.0 | 76.6 | 78.6 |
| | evening | 26.2 | 27.8 | 26.0 | 28.0 | 82.1 | 75.1 | 79.0 |
| | | | | | | | | |
| | morning | 27.4 | 27.5 | 27.7 | 27.9 | 63.1 | 71.8 | 79.1 |
| 8-Oct | afternoon | 29.9 | 27.7 | 29.1 | 28.8 | 68.0 | 66.7 | 81.4 |
| | evening | 31.4 | 28.9 | 30.1 | 29.2 | 65.0 | 54.3 | 71.2 |
| | | | | | | | | |
| | morning | 25.0 | 25.0 | 24.9 | 24.8 | 92.0 | 89.6 | 71.5 |
| 9-Oct | afternoon | 28.2 | 26.6 | 27.5 | 26.2 | 88.0 | 76.3 | 79.8 |
| | evening | 27.9 | 25.5 | 29.0 | 28.8 | 76.0 | 69.1 | 67.1 |
| | | | | | | | | |
| | morning | 29.0 | 30.6 | 28.8 | 29.8 | 82.0 | 75.5 | 75.8 |
| 10-Oct | afternoon | 28.0 | 30.3 | 29.9 | 30.0 | 83.2 | 73.5 | 61.8 |
| | evening | 29.3 | 28.9 | 29.1 | 29.9 | 63.7 | 74.6 | 66.5 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 11-Oct | morning | 27.5 | 28.8 | 27.7 | 27.1 | 81.0 | 69.8 | 80.2 |
| | afternoon | 29.6 | 29.9 | 29.0 | 30.0 | 81.8 | 75.4 | 66.8 |
| | evening | 28.0 | 28.4 | 28.1 | 26.8 | 72.6 | 86.0 | 80.1 |
| | | | | | | | | |
| 12-Oct | morning | 25.5 | 28.6 | 26.1 | 26.0 | 69.1 | 77.8 | 72.7 |
| | afternoon | 29.6 | 28.7 | 27.6 | 28.1 | 79.8 | 74.3 | 63.6 |
| | evening | 25.8 | 26.9 | 27.1 | 27.0 | 82.0 | 79.8 | 68.2 |
| | | | | | | | | |
| 13-Oct | morning | 25.0 | 25.9 | 25.4 | 28.7 | 69.8 | 77.1 | 75.1 |
| | afternoon | 27.9 | 28.2 | 28.6 | 29.0 | 66.5 | 77.5 | 85.1 |
| | evening | 27.4 | 28.0 | 28.3 | 28.0 | 77.6 | 65.7 | 79.1 |
| | | | | | | | | |
| 14-Oct | morning | 25.5 | 25.7 | 25.6 | 23.2 | 65.4 | 69.6 | 82.4 |
| | afternoon | 25.8 | 25.8 | 25.8 | 73.3 | 69.6 | 87.7 | 78.4 |
| | evening | 25.7 | 25.6 | 25.6 | 23.1 | 74.9 | 72.4 | 77.4 |
| | | | | | | | | |
| 15-Oct | morning | 26.2 | 25.9 | 26.5 | 27.7 | 68.5 | 65.6 | 73.3 |
| | afternoon | 28.0 | 27.7 | 27.5 | 29.7 | 67.5 | 66.7 | 66.5 |
| | evening | 27.8 | 27.1 | 26.9 | 30.1 | 77.9 | 72.1 | 68.7 |
| | | | | | | | | |
| 16-Oct | morning | 27.0 | 27.9 | 27.1 | 26.9 | 67.7 | 90.5 | 87.6 |
| | afternoon | 27.6 | 27.3 | 26.7 | 27.9 | 73.4 | 77.5 | 76.1 |
| | evening | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 76.4 |
| | | | | | | | | |
| 17-Oct | morning | 26.8 | 26.6 | 25.9 | 25.4 | 70.6 | 86.0 | 89.0 |
| | afternoon | 27.1 | 26.9 | 26.1 | 25.6 | 65.8 | 73.0 | 68.0 |
| | evening | 26.9 | 26.8 | 25.8 | 25.2 | 63.8 | 73.2 | 53.1 |
| | | | | | | | | |
| 18-Oct | morning | 26.1 | 26.3 | 26.0 | 26.5 | 75.5 | 73.5 | 63.7 |
| | afternoon | 27.9 | 27.8 | 28.7 | 27.8 | 63.6 | 69.4 | 67.6 |
| | evening | 26.8 | 27.6 | 27.5 | 27.2 | 70.1 | 72.4 | 75.4 |
| | | | | | | | | |
| 19-Oct | morning | 27.7 | 27.6 | 27.9 | 26.9 | 74.3 | 62.2 | 68.5 |
| | afternoon | 28.0 | 28.1 | 27.8 | 28.8 | 69.2 | 67.5 | 68.7 |
| | evening | 28.1 | 27.7 | 27.5 | 27.3 | 97.0 | 89.1 | 93.0 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 20-Oct | morning | 28.2 | 28.3 | 28.0 | 27.4 | 66.4 | 68.5 | 70.7 |
| | afternoon | 29.6 | 29.0 | 29.4 | 29.7 | 65.6 | 65.4 | 68.4 |
| | evening | 29.3 | 29.1 | 28.9 | 28.8 | 86.0 | 88.7 | 90.0 |
| | | | | | | | | |
| 21-Oct | morning | 26.2 | 25.9 | 26.5 | 27.7 | 68.5 | 65.6 | 73.3 |
| | afternoon | 28.0 | 27.7 | 27.5 | 29.7 | 67.5 | 66.7 | 65.5 |
| | evening | 27.8 | 27.1 | 26.9 | 30.1 | 84.0 | 92.0 | 89.8 |
| | | | | | | | | |
| 22-Oct | morning | 27.0 | 27.9 | 27.1 | 26.9 | 67.7 | 90.5 | 88.6 |
| | afternoon | 27.6 | 27.3 | 26.7 | 27.9 | 73.4 | 77.5 | 76.1 |
| | evening | 27.7 | 27.5 | 27.6 | 27.8 | 70.5 | 74.7 | 76.4 |
| | | | | | | | | |
| 23-Oct | morning | 26.1 | 26.3 | 26.0 | 26.5 | 92.3 | 86.0 | 98.0 |
| | afternoon | 27.9 | 27.8 | 28.7 | 27.8 | 63.6 | 69.4 | 67.6 |
| | evening | 26.8 | 27.6 | 27.5 | 27.2 | 70.1 | 72.4 | 75.4 |
| | | | | | | | | |
| 24-Oct | morning | 28.1 | 27.0 | 27.4 | 26.0 | 96.0 | 91.0 | 89.9 |
| | afternoon | 29.5 | 28.0 | 27.6 | 29.9 | 58.7 | 64.5 | 68.4 |
| | evening | 25.6 | 26.8 | 26.7 | 26.5 | 59.8 | 64.3 | 61.7 |
| | | | | | | | | |
| 25-Oct | morning | 25.0 | 25.4 | 25.5 | 24.9 | 93.0 | 77.9 | 88.1 |
| | afternoon | 27.6 | 27.4 | 26.9 | 29.0 | 64.5 | 66.7 | 65.4 |
| | evening | 28.1 | 28.1 | 28.0 | 28.3 | 68.6 | 82.0 | 70.9 |
| | | | | | | | | |
| 26-Oct | morning | 25.5 | 26.0 | 26.3 | 26.0 | 77.0 | 86.0 | 83.3 |
| | afternoon | 29.9 | 27.7 | 29.1 | 28.8 | 68.0 | 66.7 | 81.4 |
| | evening | 31.4 | 28.9 | 30.1 | 29.2 | 65.0 | 54.3 | 71.2 |
| | | | | | | | | |
| 27-Oct | morning | 25.0 | 25.0 | 24.9 | 24.8 | 92.0 | 89.6 | 71.5 |
| | afternoon | 28.2 | 26.6 | 27.5 | 26.2 | 88.0 | 76.3 | 79.8 |
| | evening | 27.9 | 25.5 | 29.0 | 28.8 | 76.0 | 69.1 | 67.1 |
| | | | | | | | | |
| 28-Oct | morning | 26.4 | 26.3 | 26.5 | 27.5 | 69.6 | 76.4 | 72.0 |
| | afternoon | 26.4 | 26.5 | 26.0 | 27.0 | 74.9 | 85.9 | 79.3 |
| | evening | 27.7 | 27.9 | 27.8 | 27.7 | 68.1 | 72.0 | 71.8 |
| | | | | | | | | |
| 29-Oct | morning | 25.9 | 26.3 | 26.2 | 26.1 | 68.4 | 83.2 | 77.9 |
| | afternoon | 26.5 | 26.8 | 26.4 | 27.0 | 67.0 | 76.6 | 78.6 |
| | evening | 25.8 | 26.0 | 25.5 | 24.8 | 95.0 | 92.0 | 91.2 |
| | | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30-Oct | morning | 29.5 | 28.0 | 27.6 | 29.9 | 58.7 | 64.5 | 68.4 |
| | afternoon | 25.6 | 26.8 | 26.7 | 26.5 | 59.8 | 64.3 | 61.7 |
| | evening | 25.5 | 26.0 | 26.3 | 26.0 | 77.0 | 86.0 | 83.3 |
| | | | | | | | | |
| 31-Oct | morning | 25.0 | 25.4 | 25.5 | 24.9 | 93.0 | 77.9 | 88.1 |
| | afternoon | 27.6 | 27.4 | 26.9 | 29.0 | 64.5 | 66.7 | 65.4 |
| | evening | 28.1 | 28.1 | 28.0 | 28.3 | 68.6 | 82.0 | 70.9 |
| | | | | | | | | |

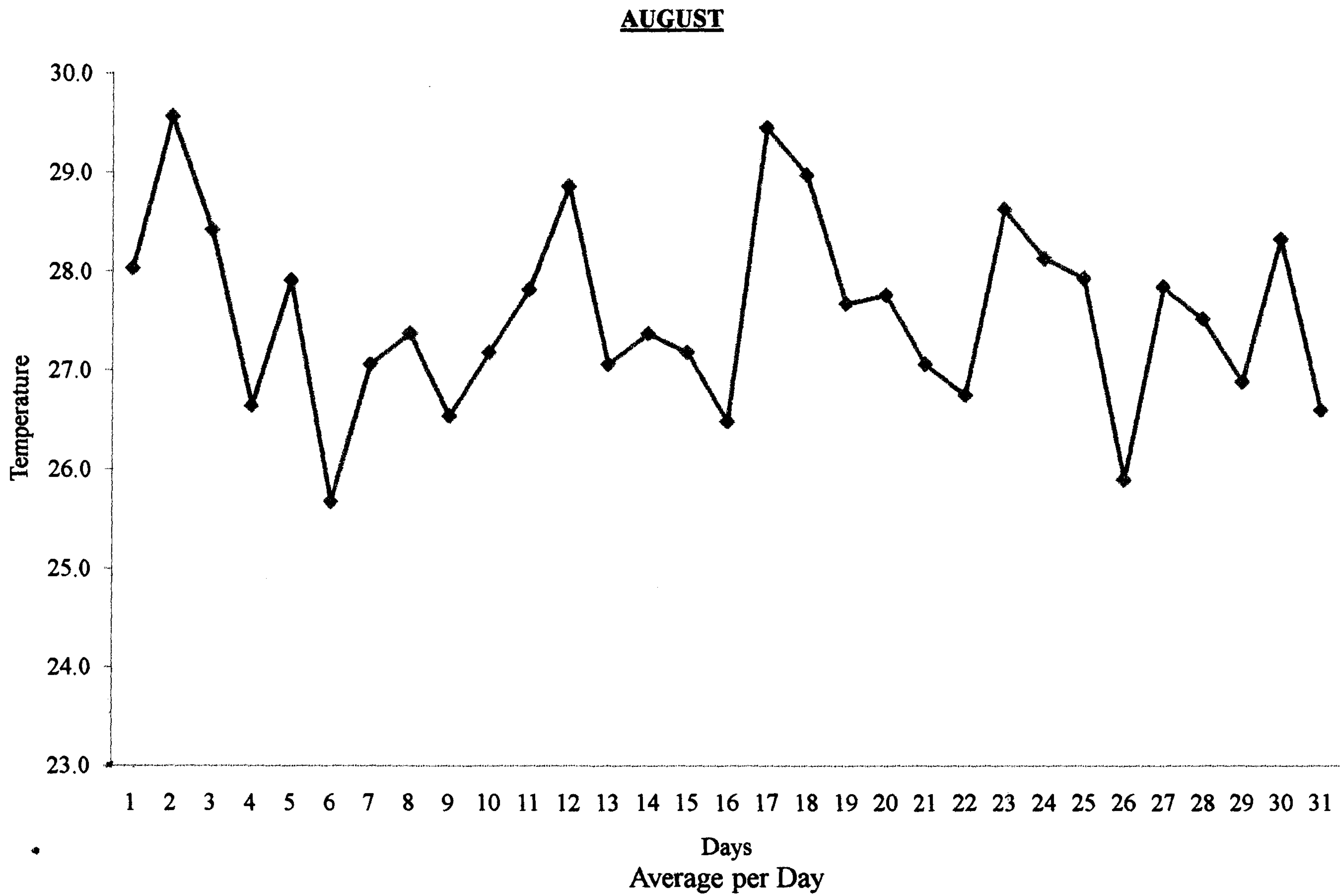



Fig. 1(a) Silo Temperature ($^{O}C$)

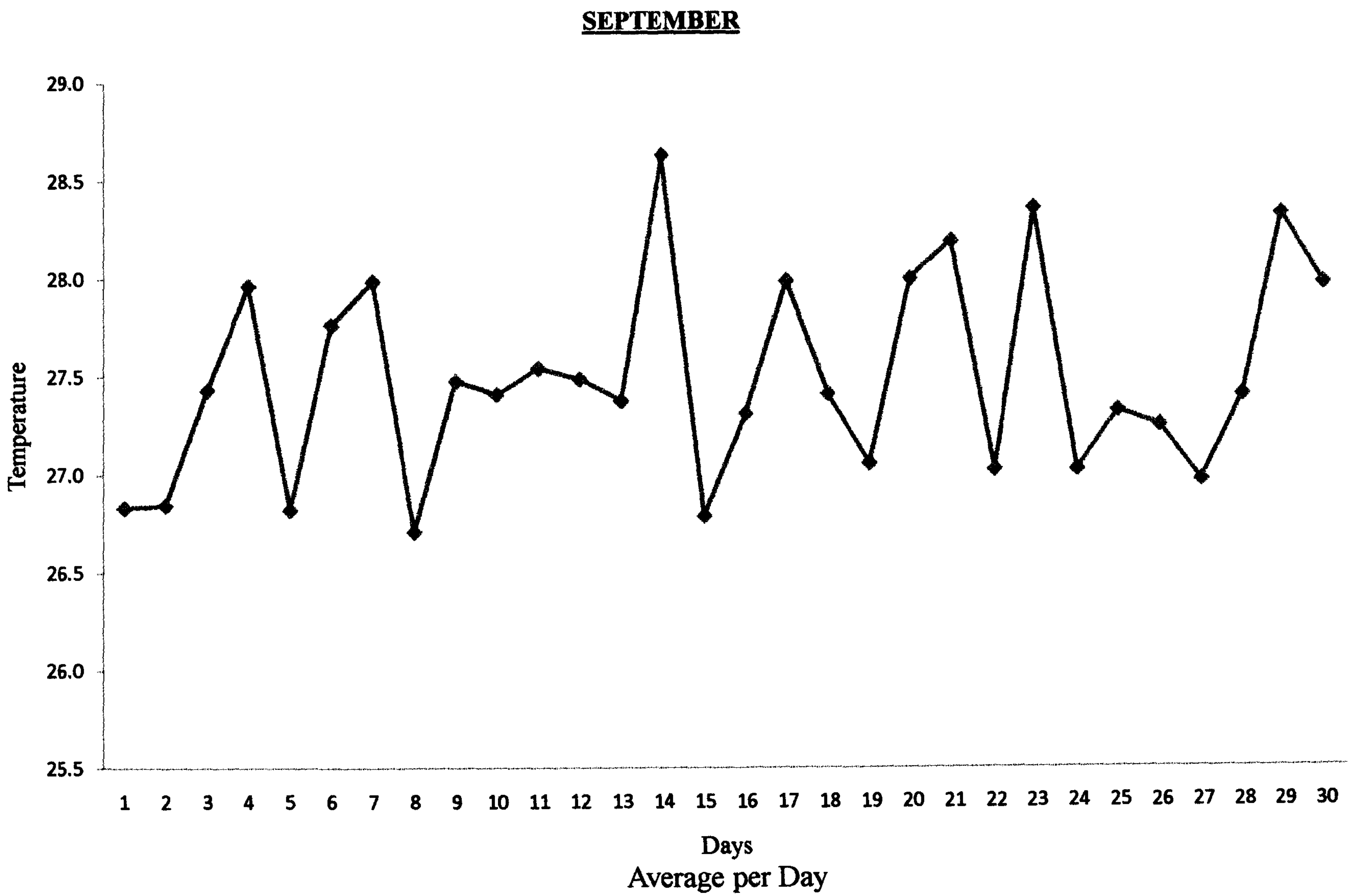



Fig. 1(b) Silo Temperature ($^{O}$C)

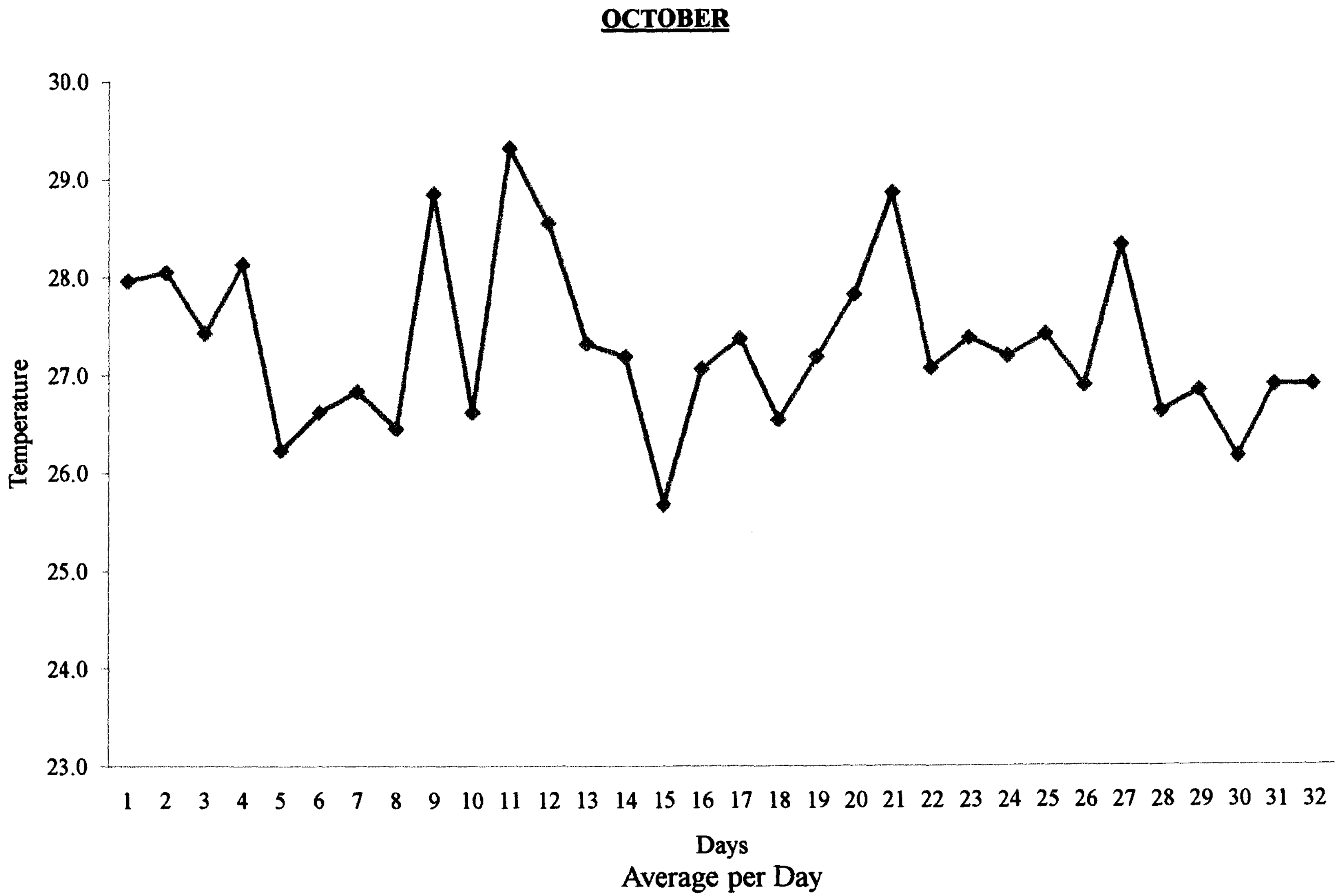



Fig. 1(c) Silo Temperature ($^{O}C$)

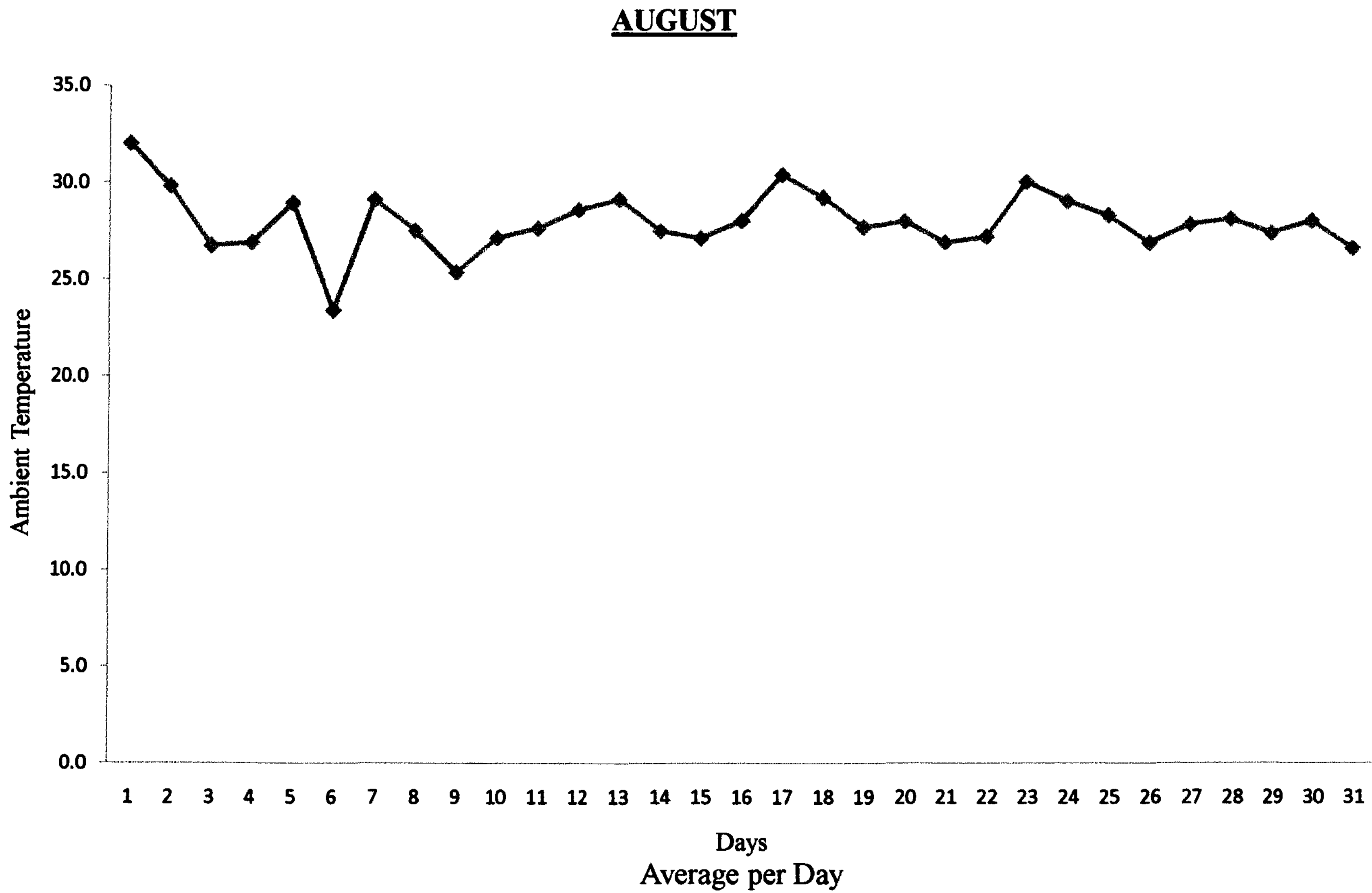



Fig. 2(a) Ambient Temperature of Silo Environment

## SEPTEMBER

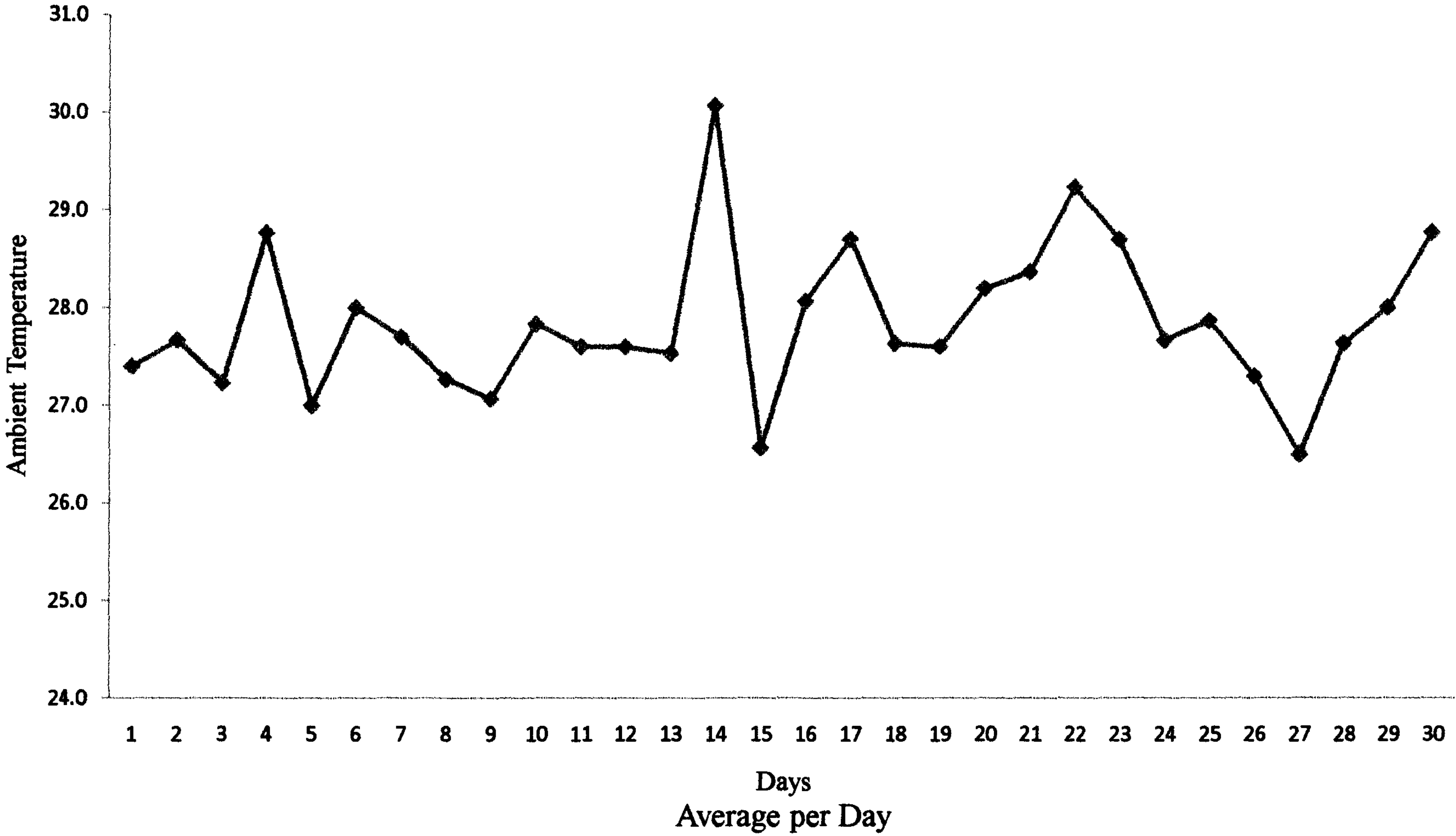



Fig. 2(b) Ambient Temperature of Silo Environment

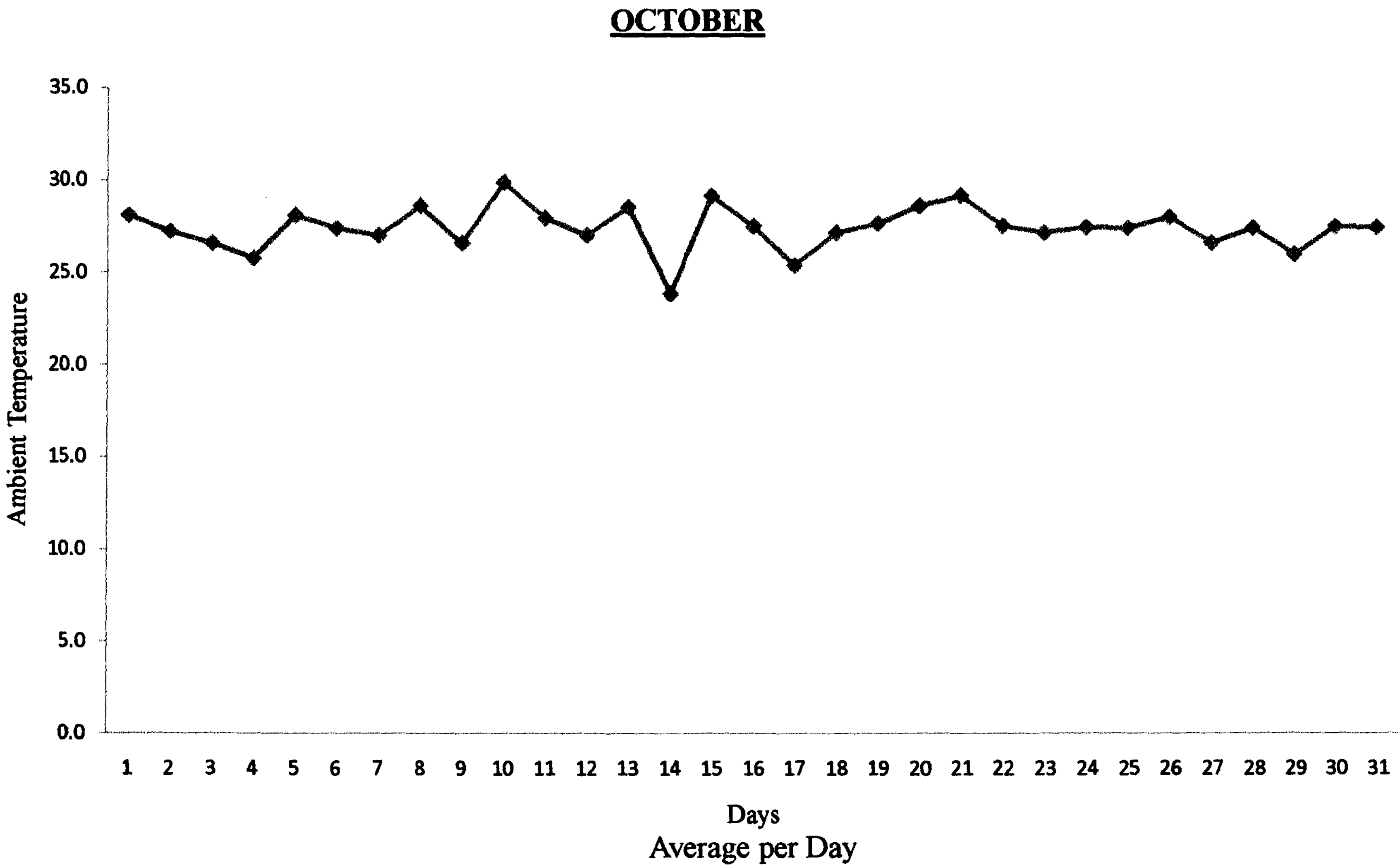



Fig. 2(c) Ambient Temperature of Silo Environment

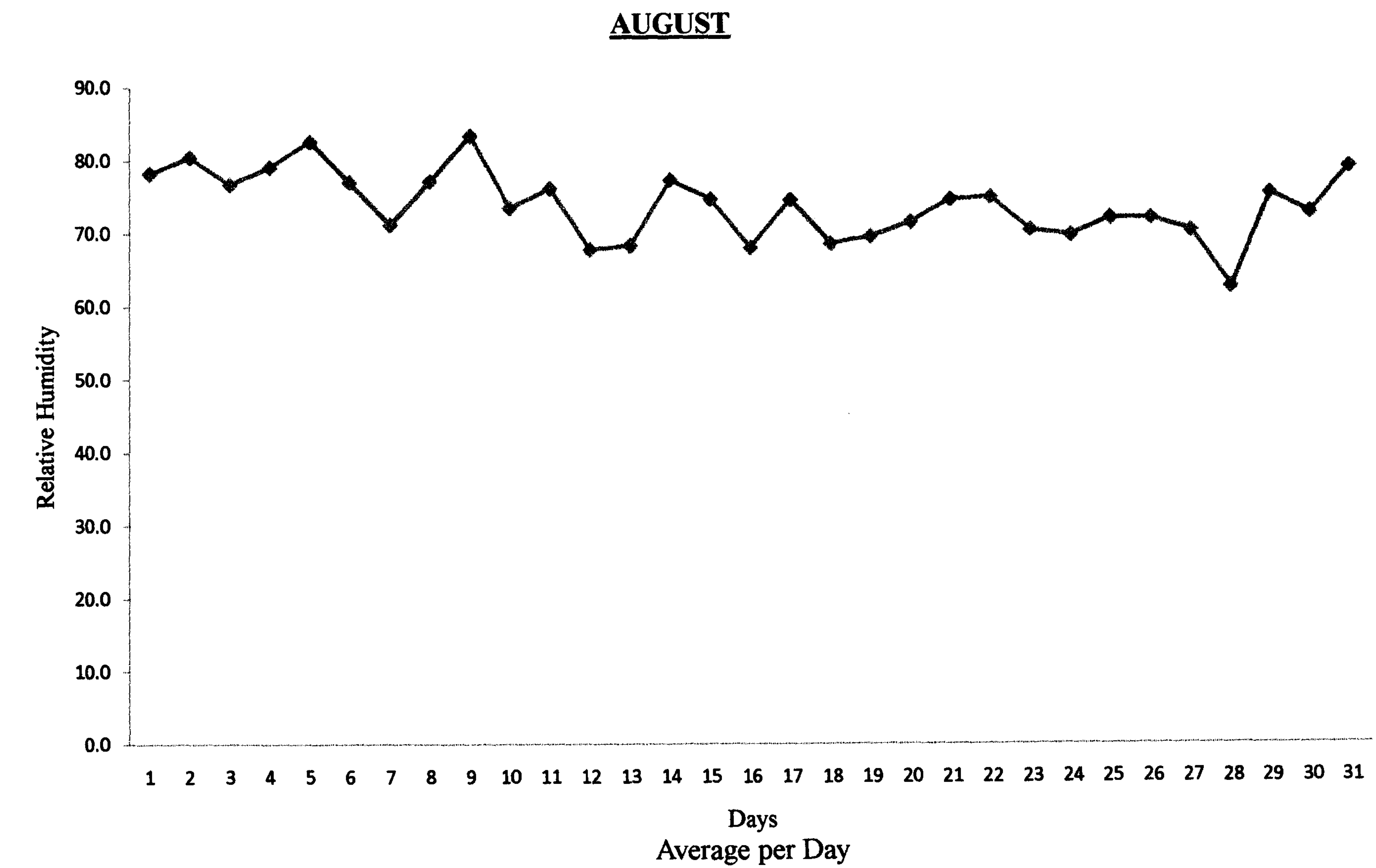



Fig. 3(a) Silo Relative Humidity

## SEPTEMBER

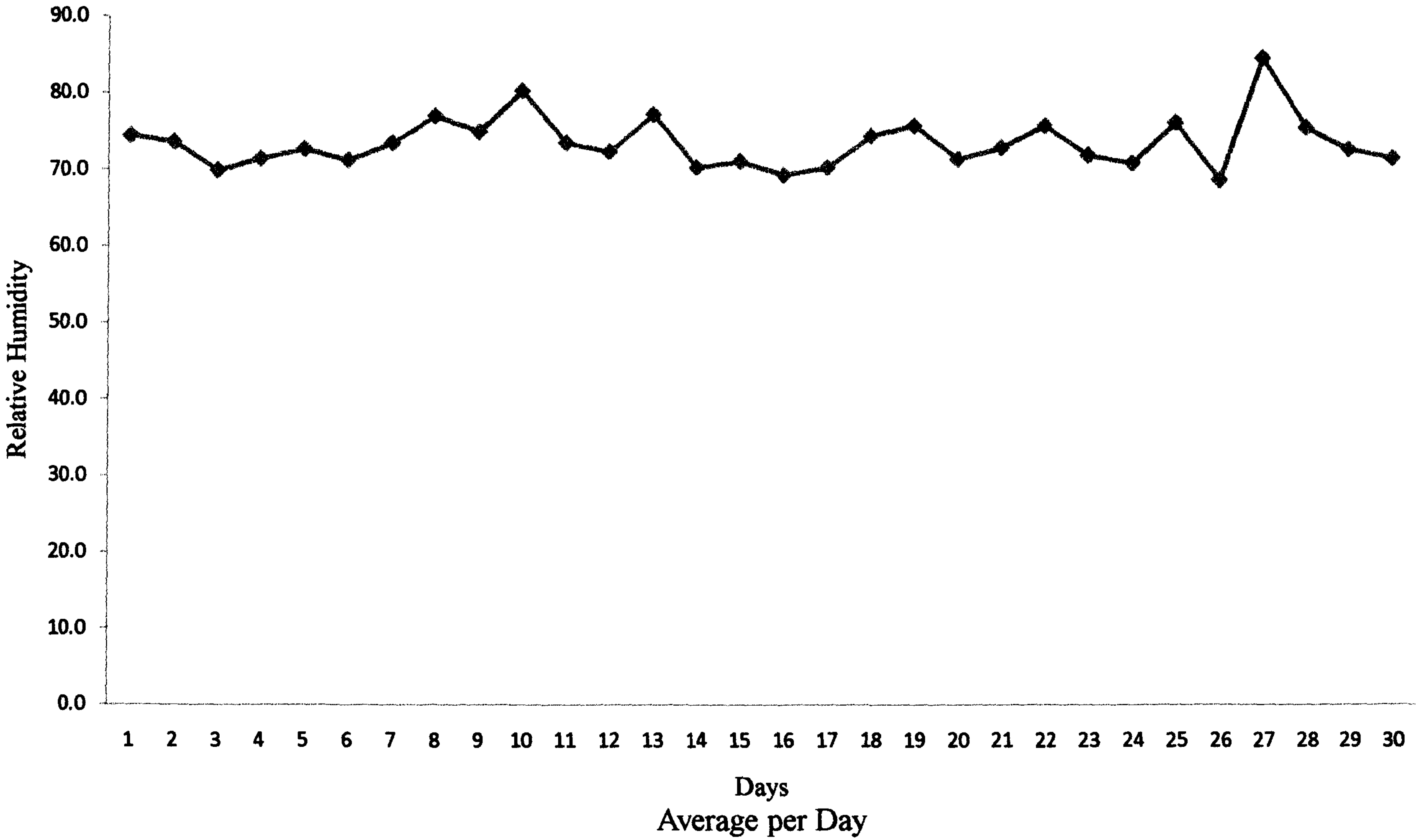



Fig. 3(b) Silo Relative Humidity

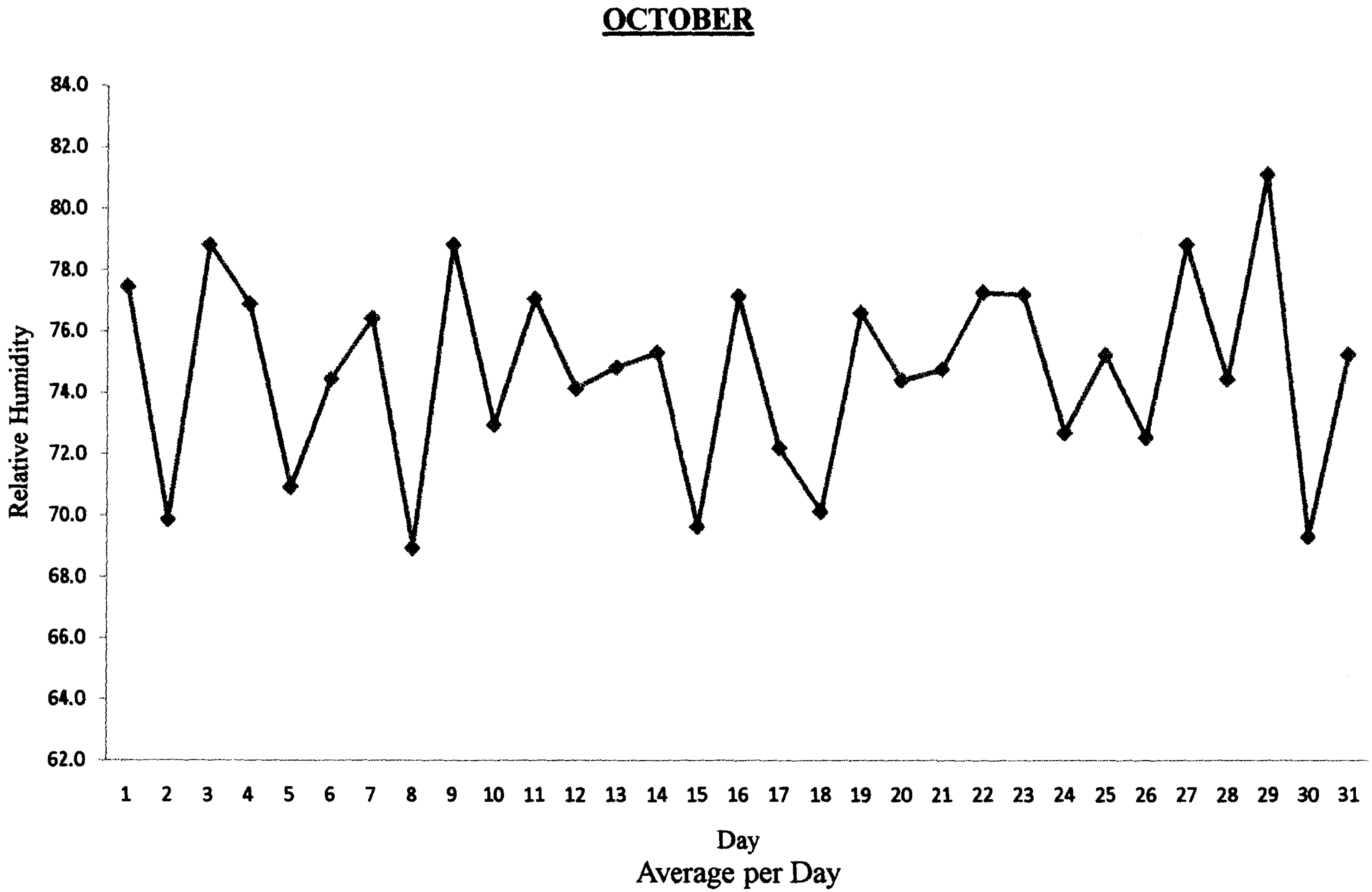
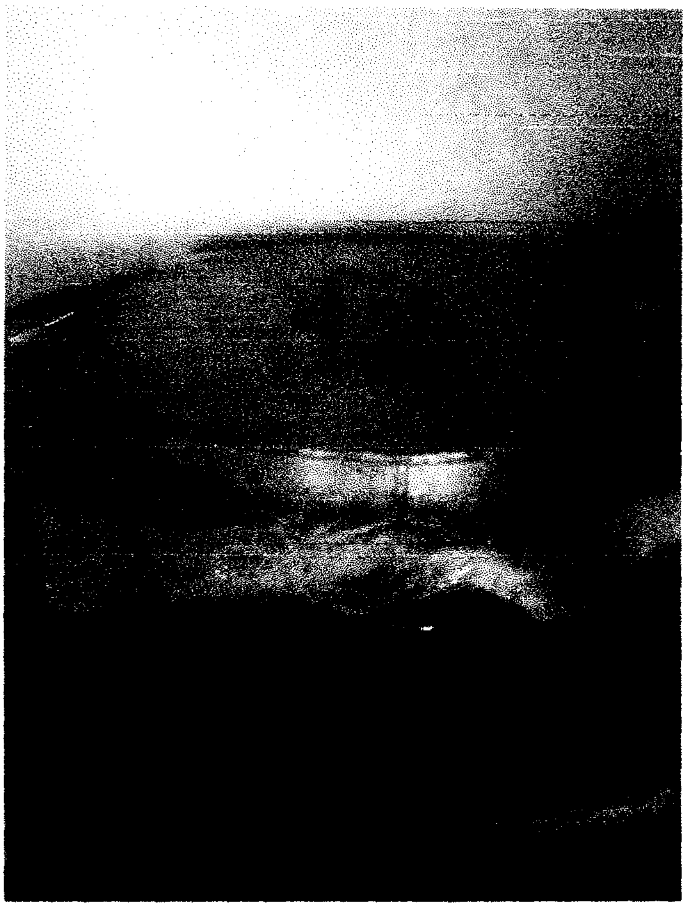


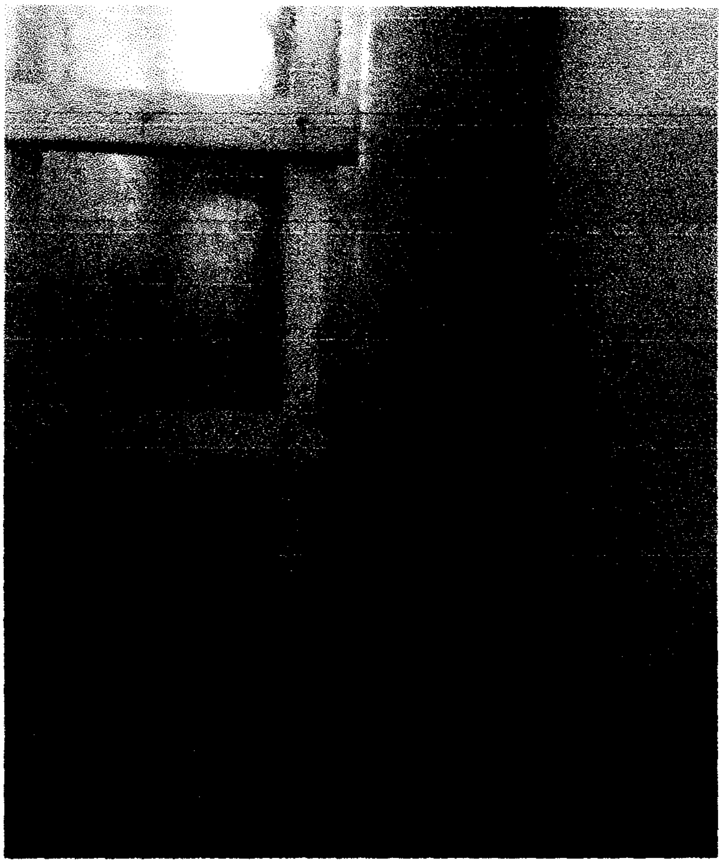

Fig. 3(c) Silo Relative Humidity

Appendix 1: The Metallic Grain Silo



Appendix 2 The Top of the Silo

Appendix 3 The Middle Access Point



Appendix 4 The Bottom Access Point