HEAT TRANSFER PHENOMENON IN SOME SELECTED YAM STORAGE BARN IN MINNA (NIGER STATE).

BY

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE AWARD OF BACHELOR OF ENGINEERING DEGREE (B.Eng.) IN AGRICULTRAL ENGINEERING, FEDERAL UNIVERSITY OF TECHNLOGY, MINNA, NIGER STATE, NIGERIA.

JANUARY, 2001.

CERTIFICATION

This is to certify that this project was carried out by POPOOLA SEGUN OLAYEMI in the department of Agricultural Engineering, Federal University of Technology, Minna.

.... 22/01/2001...

ENGR. (MRS.) Z.D. OSUNDE DATE

SUPERVISOR

.... 16/1/2001...

EXTERNAL EXAMINER DATE

.... 22/01/01...

ENGR. DR. M.G. YISA DATE

HEAD OF DEPARTMENT

DEDICATION

This project work is dedicated to the almighty God and to my parent Elder N.A. POPOOLA and Mrs S. POPOOLA

ABSTRACT

The study of heat transfer phenomenon in some selected yam storage barn was carried out using three different storage structures, all of which has a replica. The structure used; pit storage barn, improved storage barn, and local storage barn. The mode of heat transfer is conduction, convection and radiation. During the cause of study it was discovered that the effect of conduction and convection was more pronounced in all the barns, while that of radiation was very minimal with local having the highest values followed by pit and reduced to zero level in the improved storage structure. The overall average minimum and maximum heat transfer recorded throughout the period, pit has the highest, followed by local and lastly improved . Throughout the period of storage, pit has the least minimum and maximum recorded values of air temperature and soil temperature. This was followed by the improved and finally local storage barn, in all outside air temperature and soil temperature has the highest. The reverse was the case in term of relative humidity. All these; air temperature, soil temperature and relative humidity plays a greater role in the self life of the stored tubers.

ACKNOWLEDGEMENT

My everlasting gratitude goes to the almighty God for His protection and guidance throughout the training period and until date.

I wish to express my humble appreciation to my supervisor. Engr. (Mrs.) Z.D. Osunde for her close supervision and valuable assistance offered me during my project work period. In the same vein I wish to express my profound gratefulness to the Head of the Department Eng. Dr. M.G. Yisa and to the esteem lecturers of the department of Agricultural Engineering Federal University of Technology, Minna.

I am short of words to express my very special thanks to my beloved parents Elder N.A. Popoola and Mrs. S. Poppola for the fulfillment of parental roles in my life. My thanks also goes to my brothers; Abayomi Popoola and his wife Mrs. Florence Popoola, Mr. Okanlawon Isiaka Master Toyin Popoola, Pastor Okanlawon olanrewaju and to my Aunt Mrs Mopelola Ganiyu and to my beloved Sister Omolola Popoola and also Olawumi Popoola and Ayobami Adio, Not forgetting my uncle Elder S.O. Adio.

Very special thanks to the family of Dr. J.O. Oladiran for their support, encouragement, and radiating love. Also to the family of Elder E.D. Imeh and Nwachukwu family I say a big thank you. My very special thanks to all NAAS members for their spiritual and moral support. My thanks goes to Silas E.A., Adeniyi O.A., Adewumi E.B., Benjamin, Fikayo, Joel and Samson.

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TABLE OF CONTENTS

CHAPTER FOUR

CHAPTER FIVE

LIST OF TABLES

LIST OF FIGURES

ABREVIATION, SYMBOLS AND NOTATIONS

α	-	Heat transfer coefficient	W/M^2K
λ	-	Thermal conductivity	W/MK
∂	-	Wall thickness	M
T	-	Temperature	k
q	-	Rate of heat transfer	W/MK
qr	-	Rate of heat transfer through radiation	W/MK
q_{Av}	-	Average heat transfer rate	W/MK
E	-	Configuration factor, depend upon the emissively of Each surface relative view	
T_{Av}		Average Temperature	K
K_1	-	Overall heat transfer coefficient(conditional Convention) for pit and local storage barn:	WM^2K
K2	-	Overall heat transfer coefficient (cond. & Conv) for Improved storage barn:...........	W/M^2K
h-		Partial heat transfer coefficient:	(W/M^2K)
6	-	Steffan - Boltzmon constant ($5.73x10^{-8}J/M^2K^4$	
R	-	Thermal resistance	
C	-	Conductance	

CHAPTER ONE

.1.0 INTRODUCTION

Yam (dioscorea spp) is a prestigious and one of the two most popular tuber crop grown in the tropics. It is cultivated within the forest and Savannah zone of Africa. In many parts of Africa and Asia, yams are important in all aspects of the culture. In West Africa for example, Yam is a status food. It is served to the visitors and much preferred over less expensive substitute, such cassava. In West Africa yam serve as the preferred staple food.

Only a few species of yams are cultivated as food crops, four species i.e Dioscorea alata, Dioseorea cayenensis, Dioscorea esculenta and Dioscorea rotundata are regularly grown in Africa and Asia. The area of extensive yam cultivation is limited by human as well as edaphic factors. Yam required a high level of soil fertility and large quantities of water over a relatively long (6-10 months) growing season. They do not flourish in poorly drained soils and most varieties will not tolerate more than a few weeks of drought without significant losses in yield. Propagation of yam is by asexual means using pieces of tubers with buds.

Yam is a staple diet in Nigeria. As a diet, it is a source of carbohydrates, proteins, vitamins and minerals. Yam supplied about 20% of daily calories intake in Nigeria. Yam is process into many local diets such as pounded yam, yam cakes, yam chips, yam rivilege, yam flour etc. Most traditional festival is centered around the crop. This ıcreases the rate at which people develop interest on the crop. Nearly in every locality ıe demand for yam is very high, therefore the rate at which yam is been consume is elatively high.

1.2.0 GEOGRAPHICAL AREA WHERE YAMS ARE GROWN

Yam is mostly cultivated in many parts of Africa and Asia. With Nigeria having the larger share in the cultivation and production of yam. The proportion of production of major yam producing countries isShow in the table below.

TABLE 1.1 MAJOR YAM PRODUCING COUNTRIES

REGION/ COUNTRY	YAM AREA (100h)	PERCENTAGE WORLD YAM AREA %	PRODUCTPRODUCTION) (1000h)	PERCENTAGE OF WORLD PRODUCTION %
WORLD	1916	100	180 37	100
AFRICA	1876	98	17701	98
WEST INDIES	13	1	164	1
NIGERIA	1334	70	13614	76
IVORY COAST	137	10	2908	16
GHANA	130	7	1046	6
TOGO	107	6	803	4
BENIN	54	3	527	3
SUDAN	36	2	199	1
JAMAICA	6	0.3	87	0.5

SOURCES: Anthony U. Osagie (1992).

The table above shows clearly that Nigeria is the major yam producing country in the whole world, about 76 percent of the world total production. However, the cultivation of yam is not evenly distributed within the country. Some states within the country are known for their high production of yam while some are lesser in the yam production in the country. Below is a table shown states with their production percentage over a period of years.

PRODUCTION FIGURES OF YAM BY STATE (%) AND NIGERIA (1000 TONS) FOR THE YEARS 1978-1984

TABLE 1.2

STATES	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84
ANAMBRA	4.6	4.3	7.8	10.6	10.5	8.3
BAUCHI	-	-	-	-	-	-
BENDEL	14.3	16.3	19.8	8.4	9.0	11.0
BORNO	-	-	-	-	-	-
C/RIVER	4.2	6.2	5.0	3.5	6.9	3
GONGOLA	20.0	21.3	13.8	1.2	4.5	3.0
IMO	3.0	3.4	4.3	5.3	5.8	12.5
KAADUNA	-	-	-	3.8	2.0	5.6
KANO	-	-	-	-	-	-
KWARA	4.6	5.2	6.6	5.5	8.2	7.0
LAGSO	-	-	-	-	4.0	-
NIGER	4.4	6.0	6.7	7.3	0.1	7.8
OGUN	0.1	0.1	-	0.1	5.3	0.3

ONDO	2.4	2.5	3.0	3.2	4.5	4.2
OYO	4.0	5.5	6.3	3.2	4.5	4.2
PLATEAU	6.8	7.9	7.6	23.8	1.4	15.0
RIVERS	1.6	0.7	1.3	1.2	-	2.3
SOKOTO	-	0.2	-	-	-	-
NIGERIA	5,780	5,060	5,281	2,260	5,910	4,987

SOURCES: Ijabo O.J. and Jirgba I.T. (1989).

Although the creation of more state out of the old one has lead to disintegration of old one, yet it can still be rightly said that Edo/Delta, Benue, niger, Imo, Gongola, Kwara and Kogi are among the state that produce high proportion of the yam crop within the country.

The production of yam is seasonal, therefore the yam harvested during the harvest period most be stored for gradual consumption until the next harvest and seed most be held for the next season's crop in addition in a non-controlled market, the value of any surplus crop tends to rise during this period provided that it is in a marketable condition. Therefore there is need to maintain the crop in prime condition for as long as possible. To meet the need of the populace all year round, and to ensure that there is no wastage during surplus time and also there is continuation of supply during post harvest period, therefore there is need for adequate means of storing yams.

1.3.0 CAUSES OF STORAGE LOSSES

The potential of the yam crop lies in its tremendous genetic diversity and ability to be stored for several months. The storage use or the tuber is ended at the termination of dormancy when new sprout develops. The main problems which are encountered during the storage of yam which causes storage loss includes the following:

DECAY:- This is the deterioration of yam tuber. It involves partial or complete decomposition of the tuber. The decay of yam is as a result of invention which is establish through wounds, bruises and natural openings such as lenticles. Lenticles invention is encountered commonly in tubers, which have been washed, incompletely dried prior to bagging and subsequently stored. The absorption of water causes the microorganism to foster the rate of decomposition of the tuber, under suitable environmental condition the disease is communicable. Falling and rising of temperature from time to time affect rotting of the tuber i.e heating and cooling by the sun.

RESPIRATION:- Yams are biologically active and respire during storage. One of the products of respiration is heat and reduction of the temperature of the crop help to reduce the rate of respiration. A damp or warm spot will increase the rate of respiration. In addition to heat, another product of respiration is moisture. The heat generated during respiration creates hot pockets in the structure or causes moisture migration resulting in deterioration of the quality. The heat and moisture from such a 'hot spot' can spread by convection encouraging moulds and bacteria, which in turn respire and give off more heat and moisture. It thus becomes a sell generating process.

WATER LOSS:- At the storage condition of low humidity, the moisture loss takes place due to partial drying which affects the appearance due to shriveling/shrinkage. Exposure to the weather results in greater weight loss the higher the ventilation level the higher the weight loss.

SOGGING:- Sogging is the swelling of the starch which takes place at high temperature. If the temperature of storage is about 50oC, swelling of the starch takes place at still higher temperatures, gelatinization may also occur (melting and thickening).

CHEMICAL CHANGES:- The chemical composition of yam is characterized by a high moisture content, and dry matter. The dry matter is composed mainly of starch, vitamins as well as sugar's and minerals. At too low temperature the starch gets converted into sugar, which affects the taste and this affect it storage life time.

SPROUTING:- Sprouting is natural phenomenon under favourable environment, particularly temperature. Exposure of yam with its concomitant higher temperature inhibits sprouting. The higher the tuber is exposed to ventilation the less the sprouting rate.

However, it clearly shown that one of the major problems associated with yam storage is the problem of regulating the temperature of the stored house as well as regulating the relative humidity. The determination of the method or ways in which heat energy is been exchange within the storage barn is therefore paramount.

The structure, it construction, the materials used are important factors in the storing process. It is the types of material that will determine the rate of heat energy exchange within the barn and of course the design too played an important roles. The design of the structure regulates the rate of heat exchange too.

For the purpose of the research work, the storage structures used are pit storage barn, local storage barn and improve storage barn. The temperature, relative humidity, soil temperature are the parameter taking into consideration so as to determine the rate of heat transfer. The heat transfer methods are through convection, conduction and radiation.

The research work is necessary so as to provide a means where by yam can be adequately stored. The percentage loss estimated in one of the state (Niger) by Osunde, et al (1996) was about 21.22%. This show that one out of every five tuber harvested in Niger State are lost due to inadequate storage devices there is therefore a serious need to find a casting solution to the problem encountered during storage of yam crop in order to increase the farmer income and to ensure steady supply of yam all year round. This can be greatly achieved when the required temperature and humidity that is required to maintain dormoncy period and prevent all other source of problem during storage is maintain.

1.4.0 OBJECTIVE OF THE STUDY

The objectives of this project work is to achieve the following:

(A) To determine the method of heat transfer into out of the

Storage barn. And to determine the effect of heat transfer on the stored yams.

(B) To determine the effect of heat on the stored yam and how it affect its dormancy period.

(C) To compact the rate if heat transfer into and out of the selected different barn and to determine which of them is the best.

(D) To be able to conclude on which of the storage structure that has the lowest heat transfer rate and the effect on the stored yams.

1.5.0 JUSTIFICATION

This research work is justifiable in that:-

(A) Nigeria is the largest yam producer in the whole world.

Therefore to maintain regular supply of the produce throughout the year to meet the demand within and outside the country there is need for adequate storage device.

(B) As stated earlier, the losses during storage is about 21.92% in one of the largest producing state, therefore to reduce the losses and safe cost there is need to device a better mean of storing yam.

(C) The major problem encounter during yams storage comes from the effect of temperature and humidity, therefore the study of the phenomenon of heat transfer into and outside of the barn is of paramount necessary.

(D) The determination of method of heat transfer and in the determination of the best storage barn and the design of the structure that is best for yam storage.

CHAPTER TWO

2.0 LITERATURE REVIEW

Over the years effort were made by many people at different time and different location on improving the storage of yam produce. The aims of this researcher were to device a means where by losses of yam tuber during storage could be grossly reduced if not eliminated. Their focus has been of the improvement of storage structure, identifies problems associated and device means of solving it. The environmental influences on the storage was one of the major problem and so heat transfer and it's effect was greatly considered.

2.1.0 METHOD OF YAM STORAGE

A number of investigations had been carried out in order to ensure appropriate storage structures for yam tuber in the country. According to Ijabo O.J. et al (1989) four different practices was identified, and these includes, barn, platform, building and pit. Mention was also made of heaps and sheds as storage methods during transit. According to Anthony U.O. (1992), method of storage vary from delayed harvesting, or storage in simple piles or clamps to storage in buildings especially in designed for the purpose, and application of sophisticated modern technique. He however, described methods of yam storage under three broad headings;

A) Traditional storage technique

B) Improve storage technique

C) Advance storage technique.

2.1.1 TRADITIONAL STORAGE TECHNIQUES

The methods under the heading include storage of yams in ordinary store-rooms, sheds or hut especially constructed for this purpose.

2.1.2 UNDERGROUND STORAGE:

This storage technique is practiced in two forms. Some forms leave the mature tuber in the ground where it was grown and harvest the tubers whenever tuber in the ground where it was grown and harvest the tubers whenever required. Eg. A few days before the main market day. While under ground, the tubers are exposed be attack by pre-harvest pests such as yam beetles on termites.

Other former big a circular trench and line the sides with palm leaves, loose straw or other protective material. The yam tubers are arranged horizontally in the pit and covered with mulch underground storage technique is simple and in expensive, although the land occupied could be used for alternative cropping. The moisture in the tuber is conserved. However, harvesting and collection can at times be difficult since the ground often becomes hard-baked during the dry season or flooded during heavy rains. Deterioration of the tuber is speeded up due to high temperature (up to 55oC) and high humidity underground. Excessive rot and decay usually results. Insect, rabbits and mice feed at random on the stored tubers. The tubers are not suitable for subsequent storage. The method is fast been abandoned.

2.1.3 HEAP/PLATFORM STORAGE

The tubers may be heaped on the floor in huts or houses. Alternatives by the tubers are arranged on wooden platform and laterals. Five are lit weekly to fumigate the tubers which are accessible to rodents, insects and other pests hence storage losses are quite high.

2.1.4 YAM BARN

This is most popularly practiced method of storage. It provides adequate ventilation, cost of construction is minimal, and material of construction is available locally from the bush. It involves the typing of yam to rack. A large framework of poles is first erected. Living post is preferred. Long cross pole or then placed in position and tied to the erect poles with ropes. According to Adegbola et al. (1979), the space left between each pair of erect pole should be about 60-120cm. The space between the horizontal poles should be 30-60cm.

2.2.1 IMPROVED STORAGE TECHNIQUE

These involved the act of improving the existing storage method, the storage method improved includes pit, barn etc.

2.2.2 UNDERGROUND PIT

This was designed to improve underground storage method. Improved in the sense that it can be assessed, and other factor such as temperature and humidity can be check accordingly.

2.2.3 WRAPPING

The tuber is wrapped in polyethylene bag. This method was used by Thompson et al (1977). The tuber lost little during storage but considerable levels of fungal growth occurred on tuber surface and also the appeared to be a proliferation of paranchyma around verticles. Combining an effective fungicidal treatment with storage in polyethylene bags in cool storage may well be practicable.

2.3.1 MODERN STORAGE TECHNIQUE

Modern storage methods involve the use of cold store. The principle problem with these treatments is that they require a high level of technology seldom available either to the former or to the warehouse man.

2.3.2 COLD STORAGE

It has been found that the storage of yam tubers at a relative humidity of 80 percent and a temperature of 16°C largely prevent moisture losses and delays sprouting after the tubers are removed from under controlled conditions. Refrigeration storage for periods up to 8 months is costly and subject to problem due to breakdown of equipment or interruption of electrical supply.

2.4.0 STORAGE STRUCTURE

2.4.1 HEAP/PLANT FORM STORAGE

To provide adequate ventilation, with cool might air, a duct under the crop is included according to Lemnart et al (1986). The duct which is to be 200mm width and 150mm height was to be constructed in a triangular form as show in the fig. 2.1

2.4.2 UNDERGROUND PIT

The design of underground pit to stored yam as designed by Anthony (1992), measure 2.9m long, 1.3m wide and 1.5m deep and is designed to hold up to 150 tubers positioned on rocks. A staircase measuring 80cm wide and consisting of four steps was provided to lead to the floor of the pit. The trusses of the roof structure were constructed with hard wood (noko) to prevent termite attack and were covered with corrugated roofing sheets. The roof structure was designed to facilitate flow of rainwater away from the pit using a 69cm high cupola. A rectangular slot measuring 0.5m by 2m was provided in the sidewall opposite the staircase and covered with fine wire mesh. The access door is located at the base of the staircase and extends to the rooftop. A chimney measuring 18cm in diameter and 1.7m high was provided with a hood and located controlling on the roof structure. The chimney was painted with a block emulsion to assist the natural upward flow of air.

In his own designed Osuji (1987) for large-scale storage of yam tubers. An airtight house was designed such that when the door and windows are shut, an anaerobic environment was imposed on the yam tubers.

The house, 9mx9mx11m was built for 10,000 tubers. The walls were concrete while the door and windows frames were made of wood. The house had two bars of windows for maximum inlet of air at intermittent periods it was discovered the after 5 months of storage, the tuber had lost very little weight and suffered mineral micribial decay.

2.4.3 BARN STORAGE

Although the construction varies from region to region, they all have the same basic features. The barn consist of vertical from work to which the yam tubers are tied by means of local cordage material such as rafter. The frame work is made from vertical poles preferably live, 5-10cm in diameter and set in apart. The height of the poles varies from 1 to 2m. Cross member are usually of bamboo or raffia palm leaf mud-ribs.

2.5.0 ENVIRONMENTAL INFLUENCES

During storage factors that affect yams in stored are caused by environmental influences. The attacked soffered by the yam of insects, animals, pathogens spoilage increases the rate of spoilage of the stored yams. The non-living factor that affect stored yams include: Temperature, relative humidity.

According to Lennart et al (1986) High moisture content leads to storage problems since it encourages fungal and insect problems, respiration and germination. And also major factor influencing spoilage is temperature.

In a research work carried out by Ajayi and Maduekc (1990) it was discovered that the higher the ventilation level, the greater the weight loss. Exposed tubers that were subjected to direct heating and cooling of the sun and rain respectively, rotted away, the high temperature involved preventing the sprouting of the tubers. Tubers in the 14% and 3.8% ventilation level outside took a longer time to sprout thom those stored inside. In an experiment on the effect of cultural and chemical treatments on yam storage in cote d' Ivoire. It was discovered that environmental data show that pit storage reduced daily flunctuation in temperature and maintained a high relative humidity within the storage area of all time compared with sheds and barn suprisingly, tuber fresh weight was virtually unaffected by these differences in temperature and relative humidity pit and shed provided greater protection from sun and rain compared with traditional barns which reduced the weight losses in D. rotundata by 12% over a 6.5 month storage period. However, there were no difference during the first 5 month and D. alata remained unaffected by the storage system. For a storage period longer than five (5) months, the study that the storing yam tubers in covered structures was better than open barn Oliver et al (1998).

2.5.1 EFFECT OF HEAT TRANSFER ON THE STORES YAM

The purpose of storage is to prevent most important factors, sprouting and rotting. Sprouting of stored yam had great effect on the deterioration of stored yam. The rate of heat transfer thus forms the major factors that control the sprouting ability of the yam stored. Temperature flunctuation affect or increase sprout growth and likewise Direct sunlight increases sprouting.

According to Adesuyi (1977), the problem of losses in yam during storage lies in lack of proper control of physical factor such as temperature, humidity, ventilation and effect the protection from redents and other animals. In an experiment to stabilized on maintain the temperature of stored yam. the discovered that losses in weight at 20°C, 25°C, and in the yam barn (31± 4°C) were similar and more than twice that at 15°C. Moisture loss was least at 15°C prolong dormancy for four months longer than25°C or the yam barn.

2.6.0 METHODS OF HEAT TRANSFER

Heat is electromagnetic energy of every short wavelength. The wavelengths of heat energy are just shorter which seens to pridiet the energy transfer which may takes place between material body as a result of temperature difference. Heat energy can be transferred by the three following mechanism;

i) Radiation

ii) Conduction

iii) Convection

2.6.1 RADIATION

Electromagnetic wave transfer energy (both heat and light) between two bodies without necessary aid of an intervening material medium at a speed of $300x10^6 MS^{-1}$ (speed of light). This is so with solar energy through space, whereas the earth atmosphere only allow the passage of radiation at certain wavelengths and restrict that at others.

Radiant heat energy is probably the most important as this is the means by which heat from the sun arrives on the surface of the earth. Radiant heat is not related to gravity and therefore travel equally well in every direction

2.6.2 CONDUCTION

Heat transfer by the conduction is the process by which Energy is transferred from atom to atom through a material or from one material to another in direct contact. Conduction is the primary means of actual heat transfer to the air in the convention process with air being the medium of transport over large distances. Under this mechanism the heat passes through a substance from point to point by means of the transfer of adjacent molecular motions. Since air is a poor conduction thus types of heat transfer can be virtually neglected in the atmosphere, but it is important in the ground.

When a temperature gradient exists in a body, there is an energy transfer from the high temperature regions to the low temperature region. The heat transfer rate per unit area is proportional to the normal temperature gradient.

$\frac{q}{A} \propto \frac{\partial T}{dx}$ When the proportionality contant is inserted

$$q = -KA \frac{\partial T}{\partial x} \quad \text{-- (1)}$$

Where q is the heat transfer rate and $\partial T/\partial b$ is the temperature gradient in the direction of the heat flow. The positive constant K is called the thermal conductivity of the material, and the minus sign is inserted so as to indicated that heat must flow downhill sign is enserted so as to indicated that heat must flow down hill on the temperature scale.

2.6.3 CONVECTION

Convection transfer energy in two forms. The first is the sensible heat content of the air (called enthalpy by physicists) which is transferred directly by the rising and mixing of warmed air. It is defined as CPT where T is the temperature and Cp (= 1004, kg-1 k-1) is the specific heat at contant pressure (the heat absorb by also for unit temperature increase). Sensible heat is also transferred by conduction. The second form of energy transfer by convection is indirect involving latent heat. Here there is no temperature change. Whenever water is converted into water vapour by evaporation (or boiling) heat is required. This is referred to as latent heat of vaporization (2). At 0oC, L is 2.50 x106j kg -1of water or 579 more generally, L(106 jgg-1) = (2.5-0.00 2351).

2.6.4 THERMAL CONDUCTION.

The equation q = -KA dT/dx is the defining equation for thermal conductivity. Based in this definition, experimental may be made to determine the thermal conductivity of different materials, Thermal conductivity indicate how fast heat will flow in a given material. It has the units of watt per meter per Celsius degree (W/m oC), or Btu/hift of. The Btu is the British thermal unit, where is a measure of quantity of heat one Btu is the heat required to raise the temperature of one pound of water 1oF. Thermal conductivity is desisted by K.

2.6.5 HEAT TRANSFER IN YAM STORAGE BARNS

Although one is more pronounced than the other, yet heat energy is transferred by the three processes. The nature of the materials used in the construction plays an important role in the transfer of heat energy either into or outside the structure. The temperature inside a building is affected by its shape, orientation, the materials of construction and shading.

2.6.6 TRASFER OF HEAT BY RADIATION

Radiant heat energy requires no material medium, it is the means by which heat from the sun arrives on the surface of the earth. The arrival of heat energy on the earth surface on the heating of the earth surface has the following effects on the environment, which thus affect the storage structure and the stored produce.

(a) The moisture content of the soil is heated up and this increase the amount of moisture content in the air, this directly affect the humidity of the atmosphere, since the content of the moisture in the air. The relative humidity of the parcel of air will obviously change if either its temperature or its mixing ratio is changed. Therefore, changes in atmospheric temperature with respect to the storage barn will determine the direction of heat transfer either into the barn or out of the barn depending on the temperature gradient. According to Roger G. Barry and Richard J. Chorley (1992), relative humidity varies inversely with temperature during the day, tending to be lower in the early afternoon and higher at night.

(b) The radiant heat energy that falls on the structure on the outer surface. The structure also absorb heat from the sun. the radiant heat energy absorb depends on the intensity of the sun and also thermal conductivity of the materials used in the construction of the barn. The heat energy received may be transferred through other means of heat transfer namely, conduction. In the case the material used in the construction is guinea corn, rice straw, the degree of hotness or coldness of the inside will determine the direction of heat energy flow.

2.6.7 TRANSFER OF HEAT BY CONDUCTION

Heat energy is conducted in or out of the storage barn through the following medium;

Guinea corn stalk

Rice straw

Water vapour (saturated)

2.6.8 GUINEA CORN STALK

Heat energy is conducted in to or out of the barn depending on the temperature gradient. The rate at which heat id conducted through the stalk depends on the thermal conductivity (k) of the stalk. According to Albert G.Spencer (1982), the thermal conductivity of wood (average for soft wood) is equal to 0,80 Btu/hr/ft2 in/ (1.3445w/m°c, note 1Btu/hft °f=1.7307w/m°c). J.P. Halman (1981), thermal conductivity of maple is 0.17w/m°c (0.098Btu//hft°f)

Saw dust, 0.059w/m°c (0.034Btu/hft°f). the thermal conductivity of the stalk can thus be based using the formula $q=-kA\delta T/\delta X$

2.6.9 RICE STRAW

In a very similar way to that of guinea corn stalk, the heat energy transfer through the straw depends on the thermal conductivity of the straw. In the case where it is used together with the stalk (guinea corn stalk) to improve the local barn, the heat transfer from inside or outside can be determined using the formula t1-13=Q/A $(x_1/k_1+x_2/k_2)$

$Q=k_1 A (t_1-t_2)/D_1=K_2A (t_2-t_3)/D_2$

$Q= A (t_1-t_3)/\partial_1/k_1+\partial_2/k_2$

Where Q= heat transfer rate

A= total area (surface) of the barn

X1= thickness of the rice straw

X2= thickness of the guinea corn stalk

K1= thermal conductivity of the rice straw

K2= thermal conductivity of the guinea corn stalk

T1= outer temperature

T2= temperature in between the two stalk

T3= temperature inside the barn

AIR

Although, it has a very poor conduction of heat when it may be virtually left in the atmosphere, yet in its very minute way it does conduct with its thermal conductivity of 0.024w/m°c.

2.6.10 TRANSFER OF HEAT BY CONVECTION

The transfer of heat by convection is the process whereby the molecules of air near a hot surface is heated causing expansion and consequent rising of the air. As the heated air rises, it will pass through the vent (opening between the stalk of the barn) which takes some of the energy away. The air contacts the stalks, is cooled, slow downward as it loses energy and a connection and current has been established. The heating and cooling of the air can cause a large transfer of energy to take place.

The rate of heat transfer either in or out of the barn through convection depends on the sizes of the vent. This also varies with regards to the design and the construction i.e. these are more vent in the local barn compared to the pit ones, while the improved ones has the least. Therefore, heat energy transfer by convection will be more pronounced in local barn, followed by pit and the last improved barns.

2.6.11 THERMAL ENERGY CONVERSION IN BUILDINGS

The instantaneous heating (or cooling) load required maintaining an internal environment at a steady predetermined temperature depends upon the rate and direction of transfer across the enclosing walls. External transmission mode is by convection to ambient air and radiation to adjacent surfaces and to the sky. The over all heat transfer coefficient is a transfer function whose magnitude depends on the inherent insulating properties of the system boundaries, radiation heat transfers and surface boundary layer effect.

Thermal energy flow paths through building assembly are multi various. When logging is applied at the boundary of a heat container, the immediate useful result is a reduction of internal energy requirements for space conditioning. A boundary is a complicated and intricate thermal assembly. Parted energy saving exercise should not be attempted without analyzing the effects on the system as a whole.

2.6.12 HEAT GAINS AND LOSSES

The rate of artificial heat generation or removal Q to maintain a comfortable internal environment depends upon the thermal balance of the structure.

In general, $Q = Q_g \sim Q_{tr} \sim Q_a$

Where Q= rate of heat flow

Q_g= natural internal heat generation

Q_{tr}= net heat transfer across the structural boundaries

Q_a= heat required to condition air for ventilation purposes.

The natural internal heat generation Q_g accrues mainly from metabolic rates, process work, and lighting, whist the net heat transfer across the structural boundary Qtr depends upon the relative amounts of solar gains and transmission losses. The heat required to condition air for ventilation purposes Qa depends upon the necessary rate of air change and the difference between the outside environmental temperature to and the internal temperature Ti required to human consort.

The transmission loss

Qtr = EKADT, (5)

Where K = over all heat transfer coefficient (wm-2K-1) of

The boundary components for solar radiation gains,

DT = (Tsa - T2), (6)

Where Tsa is the outside sol. Air temperature, whereas, for

Transmission losses DT = (To - Ti) -- (7)

Overall heat transmission takes place by the combined Modes of convection, radiation, and mass transfer. Rate of Heat transfer by convection depend upon the nature of fluid Flow, and so knowledge of fluid dynamics is required to Ascertain connective heat transfer coefficients.

2.6.14 RADIATIVE HEAT TRANSFER WITH RESPECT TO BUILDINGS.

The evaluation of a configurative factor is often difficult and devious . Many problems encountered in the analyses of the thermal balanced of buildings can, however, often be Simplified using average effective radiation heat transfer

Coefficient hr which may be applied in a similar manner as

convection heat transfer coefficients i.e $Rr = hrA (T1 - T2) =$

$AT\sigma (T_1^4 - T_2^4)$ - (8)

Or $hr = q [\sigma(T_1^4 - T_2^4)/(T_1-T_2)$ - (9)

Now, $[(T_1^4 - T_2^4)] = (T_1^2+T_2^2)(T_1-T_2)$ (10)

Where q =heat constant

h = partial heat transfer coefficient

6 = stefon Boltz mann constant (= 5.73 x 10-8)

E = Configuration factor.

Surface temperatures encountered when considering heat transfers between the internal or external walls of buildings range from ~ 270k to ~320k. Average temperature present in the system are in the system are in the region of 295k. It is easily demonstrated that, for these temperatures,

$(T_1^2+T_2^2)(T_1+T_2) \sim 473m$ - (11)

Thus $qr = Aq64T^3_{AV}(T_1-T_2)$ (12)

Rending a close approximation. Taking a mean temperature of 295k, the relationship further simplifies to

$qr = 5.8\dot{p}A(T_1-T_2)$ (13)

Giving an equivalent radiation heat transfer coefficient

Hr = 5.8 & (wm-2x-2) - (14)

This can then be added to the convection coefficient to produce a heat coefficient, which combines the effects of convection and radiation.

This can then be added to the convection coefficient to produce a heat coefficient, which combines the effects of convection and radiation.

2.6.15 CONDUCTION HEAT TRANSFER WITH RESPECT TO BUILDINGS

STEADY-STATE ONE-DIMENSIONAL CONDUCTION

Most heat conducted through the walls of buildings flow in a Direction perpendicular to the surfaces, most transmission loss or gain calculations involve the one-dimensions Fourier equation for heat flow by conduction:

$$Qq = KA\ \Delta T/L = \Delta T/R \quad - \quad (15)$$

Where R (kw-1) is the thermal resistance opposing heat flow by conduction. Its reciprocal C is thermal conductance of the solid section. T is the temperature drop a wall of width 1 and area A.

2.6.16 COMPOSITE WALLS

If n transfer of different materials in series comprise a composite wall, the total resistance is calculated by simply summary resistance. I.e

$$Rtot = L_1/K_1A + L_2/K_2A + \ldots + L_n/KnA \quad - \quad (16)$$

And then

$$Q = \Delta T/Rtot \quad - \quad (17)$$

In n larger of different material in parallel make up a walls,

The total conductance educated from

$$Ctot = A_1K1/L_1 + A_2K_2/L_2 + \ldots\ldots\ldots + AnKn/Ln \quad - \quad (18)$$

$Qq = Ctn\ T$ - (19)

Heat transfer from inside to outside refers to age (2) and (3)

2.6.17 RADIAL FLOW CONDCUTION

Because the area A, through which heat passes, increases with radius a logarithmic mean thermal resistance obtained from integration is imployed in radial flow situations. For a pipe of length L

$R = loge\ (ro/vi)$ - (20)

Then $Qq = AT/R$ as before

The resistances are simply added to obtained the overall resistance of composite pipes.

2.6.18 CONDUCTION THROUGH A CIRCULAR WALL

In the case of a situation where by the surface area is very

Nearly the same of the external surface area, from a heat

Transfer point view, if thus is the case, then the area through

Which the heat passing is always very nearly the same. For a

Circular object of radius r, and thickness x, then the area of

Heat transfer for a length of $L = 2XrL$

Hence $q = k \times 2xrL\ (t_1 - t_2)/X$ - (21)

In the case where the internal surface area is considerably

Small then the external surface open and hence the thick circular surface does not admit of the simple treatment given in the case of thin cylinder.

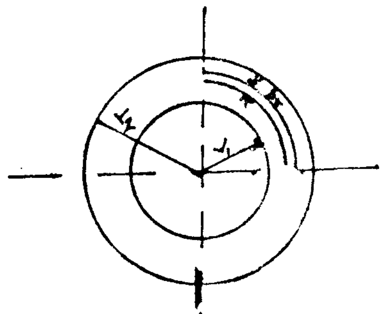


Fig. 2.4

Considered the above figure an elemental cylinder within the cylinder at radius r and thickness dr.

Let the change of temperature across this elemental cylinder =dt.

Then Qq = k2 rLdt - (22)

The negative sign is because is negative since thee is a

Temperature fall across the cylinder

$\delta t = - q/k2\Pi l \; dr/r$

$\int_{t1}^{t2} dt = -q/ k2\Pi l \int_{r1}^{r_2}$

$[t]_1^2 = - q/k2\Pi l \; [\ln r]_{r_1}^{r_2}$

$q = k2\Pi l \; [t_1-t_2]/\ln[r_2/r_1]$

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1.0 The materials used to carried one the experiment

1. Soil Thermometer
2. Mercury in glass thermometer
3. Digital temperature and humidity recorder
4. Weighing balance
5. Yams

3.1.1 SOIL THERMOMETER

Normal mercury-in-glass thermometer was used. It is enclosed in a perforated alluminium case with an opening on one side making it possible for the graduating side of the thermometer to be read.

3.1.2 DIGITAL TEMPERATURE AND HUMIDIDTY RECORDER

This is an electronic temperature and humidity recorder. It Has a high degree of accuracy and gives the value up to two Decimal place.

3.1.3 WEIGHING BALANCE

To determine either the loss or increase in mass of the yam, a

Balance was used. A direct reading balance, graduated in kilograms. And the pointer gives the direct reading of the mass placed on them.

3.1.4 MERCURY-IN-GLASS THERMOMETER

Mercury-in-glass thermometer was used to alert us during the cause of the experiment if there is any fault developed annoticed in digital temperature and humidity recorder.

3.2.0 DISCRIPTION OF STORAGE BARNS

The types of storage barn used in the experiment are:

1. Pit storage barn
2. Local storage barn
3. Improved storage barn

As shown in plate 1,2,3,4

3.2.1 PIT STORAGE BARN

The underground pit storage barn measured 1m height above

The ground level, 1m deep below the ground level, 3m long

And 2m wide. It was designed to hold more than hundred Tubers of yam. In this research work a total of 103 tubers Of yam were stored.

A staircase measuring 70cm (0.7m) wide and consisting of Four steps was provided to lead to the flour of the pit. The trusses of the roof structure were constructed using wood And then roofed using guinea corn stalk of the 1.0m height Above the ground, the guinea corn stalk was used to Construct the walls. So as to facilitate cross flow of air. The Access door which is located at the base of the staircase was Constructed using guinea corn stalk and it extended to the Roof which is removable to allow entrance into the pit. The Pit structure was located in an open space area oriented to Facilitate natural air flow through the vents.

3.2.2 LOCAL STORAGE BARN

The barn is called local because it is same as the types of Barn used by the local people within the geographical area Of the experiment site. The materials and the method used Was purely local. However, the barn was constructed Using guinea corn stalk. The stalk was tied together using Twine thread to form its wall. The storage is 1.8m height, 2.0m wide and 3.0m long. The roof made up of guinea corn stalk and other grasses to prevent water. The trusses also made of wooden poles to support the roof. The access door was also made of guinea corn stalk, it is of the same height with the wall. The floor of the barn is nothing but the original top soil of the site, cleared of grasses and other dirties materials. The local barn has wider vent compared to other type of storage structures, thus is due to the fact that the stalk are not perfectly straight and smooth. A pole is raised at the center to support the roof and also provide a place to hang instrument like thermometer. The storage is designed to accommodate over hundred of tubers. For this experiment 103 tubers of yam was stored. It was constructed in an open space area with good drainage and oriented to facilitate natural and flow through the vents.

3.2.3 IMPROVED STORAGE BARN

The barn was named improved simply because it is a modification of local storage barn. The only different was that the improved barn was lagged inside with rice straw including the roof. This was aim at cooling the inside more than the other barns.

Two replace of each storage structure was built and experiment all of which has replicate. A total of 618 tubers of yam was stored in all the storage with each has 103 tubers. Two varieties of yam was stored: Asuba and Giwa. The yam was also suited out and stored according to their sizes.

3.3.0 PARAMETERS TAKEN INTO CONSIDERATION

During the course of experiment, the parameters taken into

Consideration includes:-

1. Soil Temperature
2. Storage barn temperature
3. Relative humidity
4. Moisture content of the yam

3.3.1 SOIL TEMPERATURE

Soil temperature is normally observed at a depth of 3cm. Measuring are often taken within the enclosure of the barns

With the soil thermometer placed in a slant form at the required depth about 3cm for about 5 minute. The reading was taken at the hours of 8.00am, 12noon, 4.00pm and 7.00pm, three times in a week precisely Monday, Wednesday and Fridays. This soil temperature was recorded in degree celsius.

3.3.2 TEMPERATURE OF THE STORAGE BARN

The temperature of the barn was taken using Digital temperature and humidity recorder. To check in case of any malfunctioning of the recorder, which may be due to battery or mechanical fault. Mercury-in-glass thermometer was also hanged inside the barns. The data were taken as that of soil temperature three days per week (Monday, Wednesday, and Friday). And also four times a day. 8.00am, 12 noon, 4.00pm and 7.00pm. The temperature was also recorded in degree Celsius.

3.3.3 RELATIVE HUMIDITY

Relative humidity of the barns was determined using digital temperature and humidity recorder. The relative humidity, which was recorded in percentage, was taken. Thrice a week. At every Monday, Wednesday and Friday. It was also recorded in each of the days of 8.00am, 12noon, 4.00pm and 7,00pm respectively.

3.3.4 CONTROL EXPERIMENT

The ambient temperature and humidity and also soil temperature outside the barns was the also taken to servers as control data. The ambient temperature of the storage barn were recorded and at was also recorded along side the relative humidity of the barns. The soil thermometer was also used to record the soil temperature of the soil outside the barn. Ambient temperature was recorded in degree Celsius, relative humidity in percentage and also soil temperature in degree Celsius.

3.3.5 SOIL MOISTURE CONTENT

The moisture content of the soil was determined by taking the samples of soil in each of the barns once a month. The samples taken from each barn was weighted and then oven dried at 105°C for 24 hours. The moisture content was the calculated using the value.

3.4.0 DATA ANALYSIS

At the end of the experiment the following are the methods used for analyze the data that was collected.

1. Bi weekly and monthly average of the data for all the structure and also that of outside was determined. The parameters taken into consideration are; air temperature of the barns, relative humidity and soil temperature.

The Average (biweekly) x̄,

$$\bar{X} = \sum_{i=1}^{i=n} xi/n$$

Where n = number of data recorded over the period of two week.

Xi = the data recorded.

2. Standard deviation was calculated using the formula

$$S = \sqrt{\sum (xi - \bar{x})^2 / n}$$

Minimum and maximum values of all the biweekly average that was calculated was sorted out of the four different data i.e columns 8.00am, 12 noon, 4.00pm, and 7.00pm.

3. The relationship between some of the parameters was also determined using graphs. The relationship which includes;

(a) Soil temperature against period and compared with air temperature against periods.

(b) Air temperature against the periods of the barns.

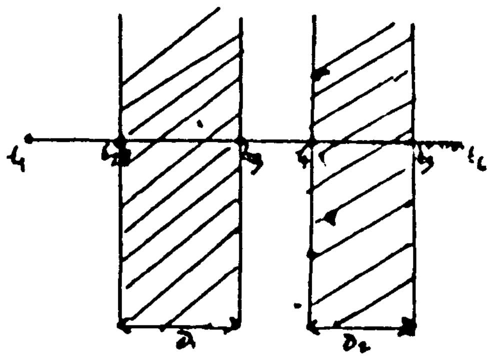
(c) Air temperature against the period of the barns ad compared with the predicted values calculated using the relation earlier mention.

3.4.1 MODE OF HEAT TRANSFER

The modes of heat transfer are the same for both pit and local Storage barn while there is a slight different in that of Improved barn.

PIT AND LOCAL STORAGE BARN

1.



The heat transfer q1

$q = \alpha a(t_1 - t_2)$ ----- [1] Convection

$q = \lambda/\delta_1 (t_2 - t_3)$ [2] Conduction

$q = \alpha b \ (t_3 - t_4)$ ------ [3] Convection

$q = \lambda/\delta_2 (t_4 - t_5)$ ----- [4] Conduction

$q = \alpha_c (t5 - t6)$ ------ [5] Convection

where α = heat transfer coefficient (W/M2K)

λ = thermal conductivity (W/MK)

δ = Wall thickness (M)

t = Temperature (K)

equating the equation [1] to [6]

$q = t_1 - t_6 / 1/\alpha a + \lambda/\delta + 1/\alpha b + \lambda/\delta + 1/\alpha c$

$q = t_1 - t_6 / \sum \lambda/\delta + \sum 1/\alpha i$

$q = K_1 [t_1 - t_6]$

where $K1 = 1 / \sum \lambda/\delta + \sum 1/\alpha i$

2. Radiative heat transfer with respect to the structure.

The effective radiative heat transfer coefficient hr may be applied in a similar manner as convective heat transfer coefficient.

$q = hrA (T_1 - T_2) = A6E (T_1^4 - T_2^4)$

or $hr = E\,6 (T_1^4 - T_2^4) / (T_1 - T_2)$

Now $(T_1^4 - T_2^4) / (T_1 - T_2) = (T_1^2 + T_2^2)(T_1 + T_2)$

$(T_1^2 + T_2^2)(T_1 + T_2) \approx$

$(T_1^2 + T_2^2)(T_1 + T_2) = 4T^3_{AV}$

Thus $q = AE64T^3_{AV} (T_1 - T_2)$

Where q = Rate of heat flow through radiation (W/MK)

A = Area, 0.036m2 (local), 0.02m2 (pit) (M)

σ = Boltzman constant (5.73x10-8) (M2K4)

T1 = Temperature outside the wall (K)

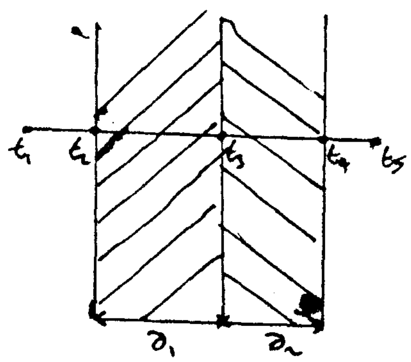
T2 = Temperature inside the wall (K)

Hr = Average effective radiative heat transfer Coefficient (W/M^2K).

E = is a configuration factor, the value of which (0.0-1.0) depends upon the emissivity of each surface relative view. Factor F_{12} between them.

For radiation transfer between two body of Infinite extent $F_{12} = [\ 1/E1 + 1/E2 - 1]^{-1}$

IMPROVED BARN



$q = \alpha a(t_1-t_2)$ ----- [1] Convection

$q = \lambda/\delta_1 (t_2-t_3)$ [2] Conduction

$q = \lambda/\delta_2 (t_3-t_4)$ ------ [3] Conduction

$q = \alpha b (t_4-t_5)$ ----- [4] Convection

equating the four equation we have

$$q = t_1 - t_5 / 1/\alpha a + \lambda_1/\delta_1 + 1/\alpha b + \lambda_2/\delta_2$$

where $\lambda_1 \neq \lambda_2$ and $\alpha a = \alpha b$ and $\delta_1 \neq \delta_2$

$$K_2 = 1 / \sum_{i=1}^{i=n} \lambda_i/\delta_i + \sum_{i=a}^{i=x} 1/\alpha i$$

CHAPTER FOUR

RESULT AND DISCUSSION OF RESULT

TABLE4.1

PIT STORAGE BARN

AIR TEMPERATURE IN DEGREE CENT. BIWEEKLY

MONTH	8:00AM	12:00NOON	4:00PM	7:00PM	MIN	MAX
FEBUARY	25.84	34.39	35.16	30.42	25.84	35.88
MARCH A	26.68	35.61	3[illegible]	32.67	26.68	36.63
MARCH B	28.48	36.87	38.39	34.03	28.48	38.39
APRIL A	29.55	35.87	36.99	32.22	29.55	36.99
APRIL B	29.37	36.15	36.79	34.08	29.37	36.76
MAY A	28.57	34.56	35.83	33.19	28.57	35.83
MAY B	26.93	31.51	33.26	30.24	26.93	33.26
JUNE	24.78	29.47	30.34	26.1	24.78	30.34

LOCAL STORAGE

TABLE4:2

AIR TEMPERATURE IN DEGREE CENT. BIWEEKLY

MONTH	8:00AM	12:00NOON	4:00PM	7:00PM	MIN	MAX
FEBUARY	25.36	33.79	35.64	30.28	25.86	35.64
MARCH A	26.61	34.62	36.74	32.32	26.61	36.74
MARCH B	29.18	35.49	38.55	34.62	29.18	38.55
APRIL A	29.6	35.86	37.42	32.33	29.6	37.42
APRIL B	29.37	36.78	36.59	34.17	29.37	36.78
MAY A	28.74	34.76	36.3	33.34	28.74	36.3
MAY B	27.15	31.38	33.33	30.5	27.15	33.33
JUNE	24.97	29.75	30.15	27.58	24.97	30.413

IMPROVED STORAGE

TABLE4:3

AIR TEMPERATURE IN DEGREE CENT. BIWEEKLY

MONTH	8:00AM	12:00NOON	4:00PM	7:00PM	MIN	MAX
FEBUARY	25.5	34.06	35.51	30.35	25.5	35.51
MARCH A	26.74	34.2	36.71	32.75	26.75	36.71
MARCH B	27.88	36.54	38.54	34.91	27.88	38.54
APRIL A	29.65	37.37	37.54	32.15	29.65	37.44
APRIL B	29.47	35.8	36.34	33.95	29.47	36.34
MAY A	27.815	34.75	36.06	33.31	27.81	36.06
MAY B	25.41	31.98	33.09	31.22	25.41	33.21
JUNE	25.8	31.17	30.79	27.64	25.8	30.04

OUTSIDE

TABLE4:4 **AIR TEMPERATURE IN DEGREE CENT. BIW**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	26.82	35.95	36.74	29.78	26.32	36.94
MARCH A	27.32	36.18	36.92	32.47	27.33	36.92
MARCH B	29.63	37.75	37.7	31.98	29.62	37.75
APRIL A	29.41	36.53	37.6	34.75	29.4	37.6
APRIL B	30.2	34.28	37.44	33.97	30.2	37.44
MAY A	28.41	36.12	37.63	33.3	28.41	37.63
MAY B	27.53	32.49	34.07	30.32	27.53	34.07
JUNE	25.5	29.67	31.1	27.5	25.5	31.1

PIT STORAGE

TABLE4:5 **SOIL TEMPERATURE IN DEGREE CENT. BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	25.84	29.29	31.44	31.37	25.84	31.45
MARCH A	27.13	31.92	32.61	31.98	27.13	32.61
MARCH B	29.01	32.37	31.3	32.87	29.01	32.87
APRIL A	29.62	32.95	32.3	30.12	29.62	32.95
APRIL B	30.78	33.56	34.15	33.68	30.78	34.15
MAY A	30.27	33.01	34.03	33.02	30.27	34.03
MAY B	29.06	29.57	30.6	29.5	29.56	30.6
JUNE	24.95	25.5	27.35	26	24.95	27.35

LOCAL STORAGE

TABLE4:6 **SOIL TEMPERATURE IN DEGREE CENT. BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	26.75	31.09	32.79	32.32	26.75	32.32
MARCH A	28	32.73	34.22	33.09	28	34.22
MARCH B	29.69	33.71	35.19	34.26	29.69	35.19
APRIL A	30.45	34.06	33.94	30.86	30.45	34.06
APRIL B	31.27	34.63	35.63	34.54	31.27	35.63
MAY A	30.53	33.22	34.79	31.07	30.53	34.79
MAY B	27.83	31.31	31.01	30.1	27.83	31.31
JUNE	25.07	26.45	37.95	37.73	25.07	27.95

IMPROVED STORAGE

TABLE4:7 **SOIL TEMPERATURE IN DEGREE CENT. BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	26.8	30.63	32.92	31.26	26.8	32.92
MARCH A	27.99	32.73	33.67	32.64	37.99	33.67
MARCH B	30.05	33.34	34.8	33.32	30.05	34.87
APRIL A	30.38	34.14	33.32	30.69	29.55	34.16
APRIL B	31.09	33.84	34.98	33.88	31.09	34.98
MAY A	31.46	33.31	34.23	34.42	30.46	34.42
MAY B	27.99	29.51	30.74	29.42	27.99	30.74
JUNE	25.45	25.85	26.98	27.85	25.45	27.85

OUTSIDE

TABLE4:8 SOIL TEMPERATURE IN DEGREE CENT. BIWEEKLY

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	26.83	39.41	42.2	33.87	26.83	42.2
MARCH A	29.03	42.1	43.1	34.5	29.03	43.1
MARCH B	31.61	42.61	42.7	37.18	31.61	42.7
APRIL A	32.85	39.76	40.5	35.16	32.85	40.5
APRIL B	33.18	44.8	44	37.08	33.18	44.83
MAY A	32.67	41.97	42.07	36.45	32.67	42.17
MAY B	29.11	32.82	36.6	32.24	29.19	36.6
JUNE	25.47	28.7	33.1	28.25	25.47	33.1

OUTSIDE

TABLE4:12 **RELATIVE HUMIDITY IN PERCENTAGE BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	21.62	15.39	15.06	23.9	15.066	26.9
MARCH A	16.44	11.88	11.7	16.4	11.7	16.45
MARCH B	40.45	32.44	20.01	26.96	20.08	40.45
APRIL A	62.33	43.08	37.06	51.02	37.26	62.33
APRIL B	65.17	37.38	35.88	44.62	37.38	65.17
MAY A	67.09	42.47	37.08	47.65	37.08	67.09
MAY B	73.39	60.37	54.25	63.1	54.25	73.39
JUNE	77.63	666.23	61.83	78.45	61.83	78.45

PIT STORAGE BARN

TABLE4.13

MONTH	AIR TEMPERATURE MINIMUM	AIR TEMPERATURE MAXIMIUM	SOIL TEMPERATURE MINIMIUM	SOIL TEMPERATURE MAX	RELATIVE HUMIDITY MIN	RELATIVE HUMIDITY MAX
FEBUARY	25.84	35.635	25.84	31.45	15.5	22.48
MARCH	27.535	37.525	27.7	33.045	18.99	33.87
APRIL	29.455	36.455	30.195	33.38	38.8	65.239
MAY	27.755	34.34	28.94	32.195	51.29	72.89
JUNE	24.78	30.34	24.95	27.35	69.77	82.8

LOCAL STORAGE BARN

TABLE4.14

MONTH	AIR TEMPERATURE MINIMUM	AIR TEMPERATURE MAXIMIUM	SOIL TEMPERATURE MINIMIUM	SOIL TEMPERATURE MAX	RELATIVE HUMIDITY MIN	RELATIVE HUMIDITY MAX
FEBUARY	25.86	35.64	26.743	32.32	16.06	23.39
MARCH	28.01	37.877	28.904	34.86	17.8	32.58
APRIL	29.68	37.115	30.869	34.94	37.925	63.292
MAY	27.88	34.646	29.143	32.754	49.496	70.95
JUNE	24.967	30.413	25.07	27.95	69	77.3

TABLE 4.15

IMPROVED STORAGE BARN

MONTH	AIR TEMPERATURE MINIMUM	AIR TEMPERATURE MAXIMIUM	SOIL TEMPERATURE MINIMIUM	SOIL TEMPERATURE MAX	RELATIVE HUMIDITY MIN	RELATIVE HUMIDITY MAX
FEBUARY	25.5	35.515	26.8	32.925	15.87	24.075
MARCH	27.96	37.855	28.37	34.37	17.87	33.65
APRIL	29.265	36.88	30.5	34.62	38.925	64.94
MAY	27.51	34.46	29.065	32.585	49.73	72.26
JUNE	25.47	30.34	25.45	27.3	69.135	78.1

OUTSIDE

TABLE 4.16

MONTH	AIR TEMPERATURE MINIMUM	AIR TEMPERATURE MAXIMIUM	SOIL TEMPERATURE MINIMIUM	SOIL TEMPERATURE MAX	RELATIVE HUMIDITY MIN	RELATIVE HUMIDITY MAX
FEBUARY	26.32	36.94	26.828	42.2	15.057	23.9
MARCH	28.713	38.03	30.407	43.821	17	31.249
APRIL	30.175	37.513	33.017	43.02	37.418	63.758
MAY	27.938	35.177	31.115	39.123	45.808	70.477
JUNE	25.5	31	25.467	33.1	61.833	77.633

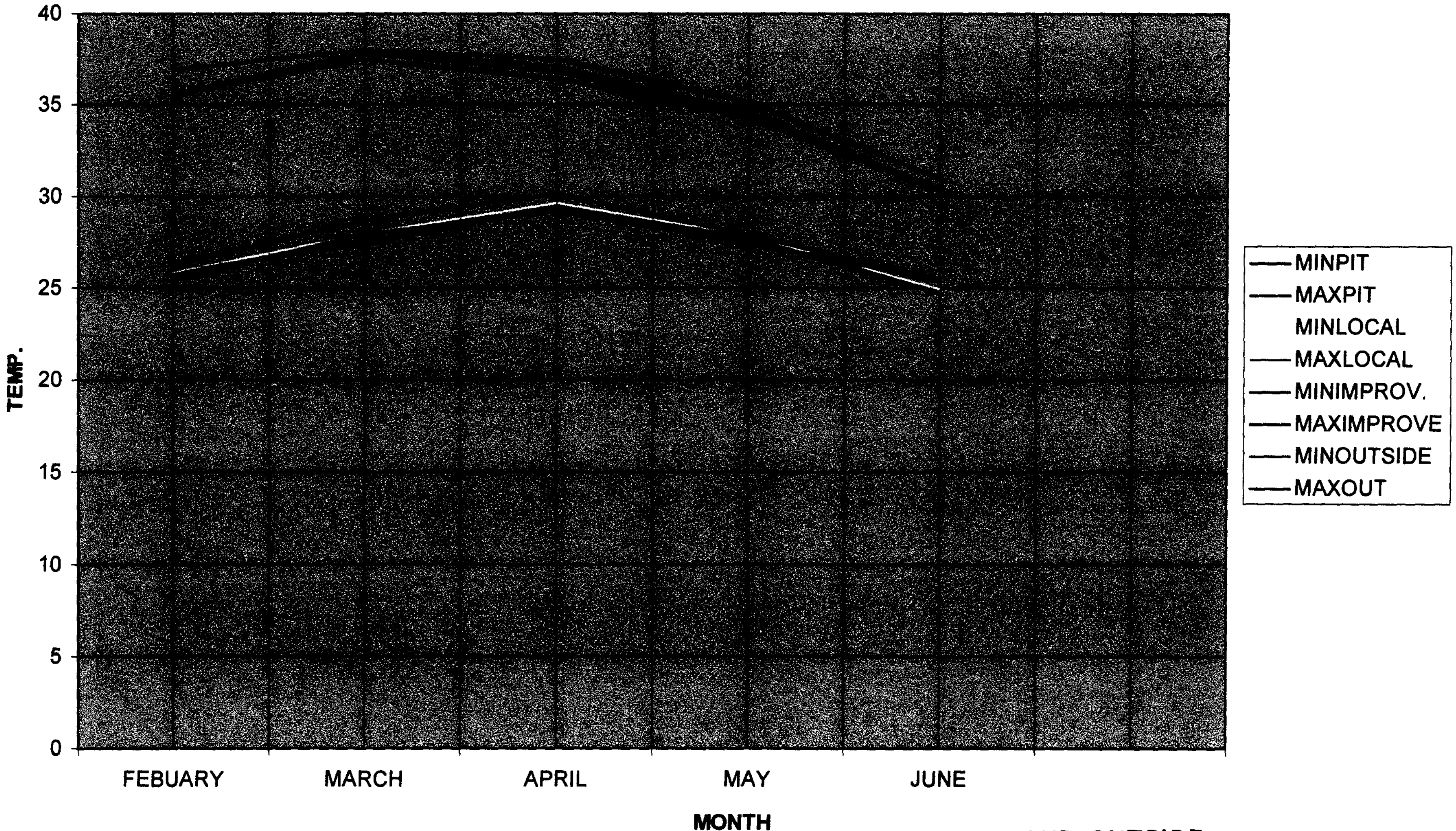


FIG. 4·1 MIN AND MAX AIR TEMP. FOR PIT. LOCAL, IMPROVE AND OUTSIDE

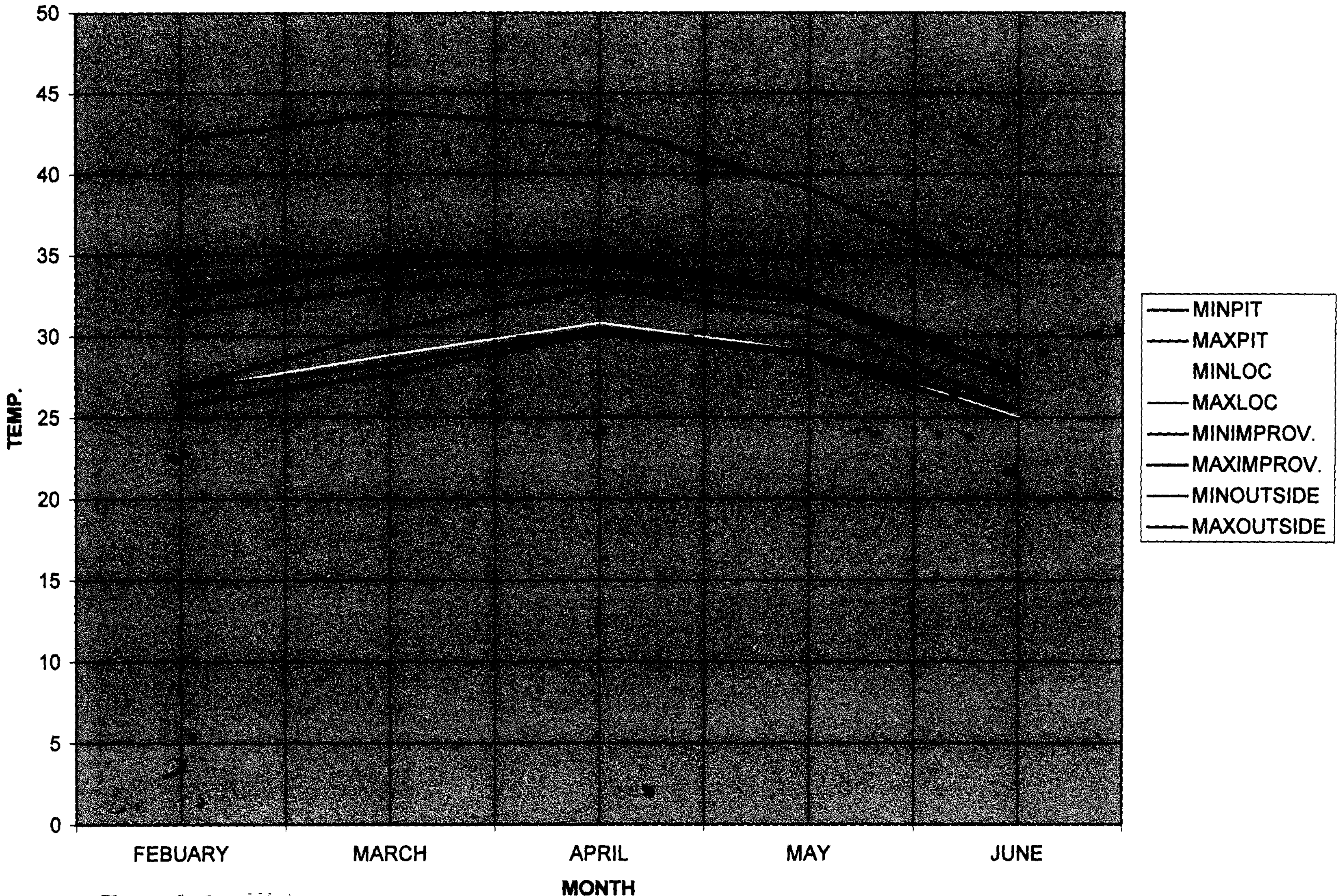


FIG 4.2 MIN AND MAX SOIL TEMP. FOR PIT, LOCAL, IMPROVE AND OUTSIDE

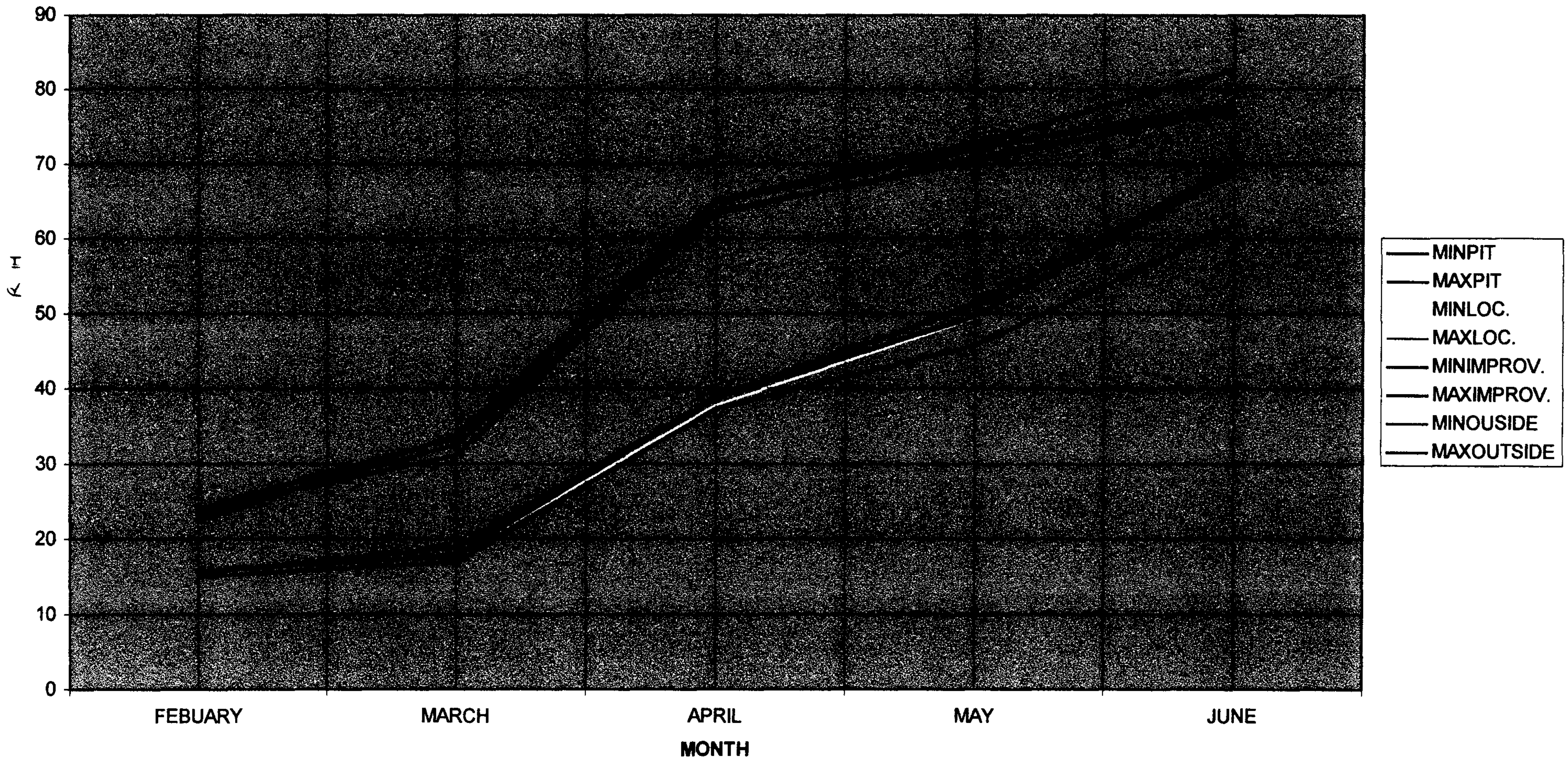


FIG 4·3 MIN AND MAX RELATIVE HUMIDITY FOR PIT, LOCAL, IMPROVE AND OUTSIDE

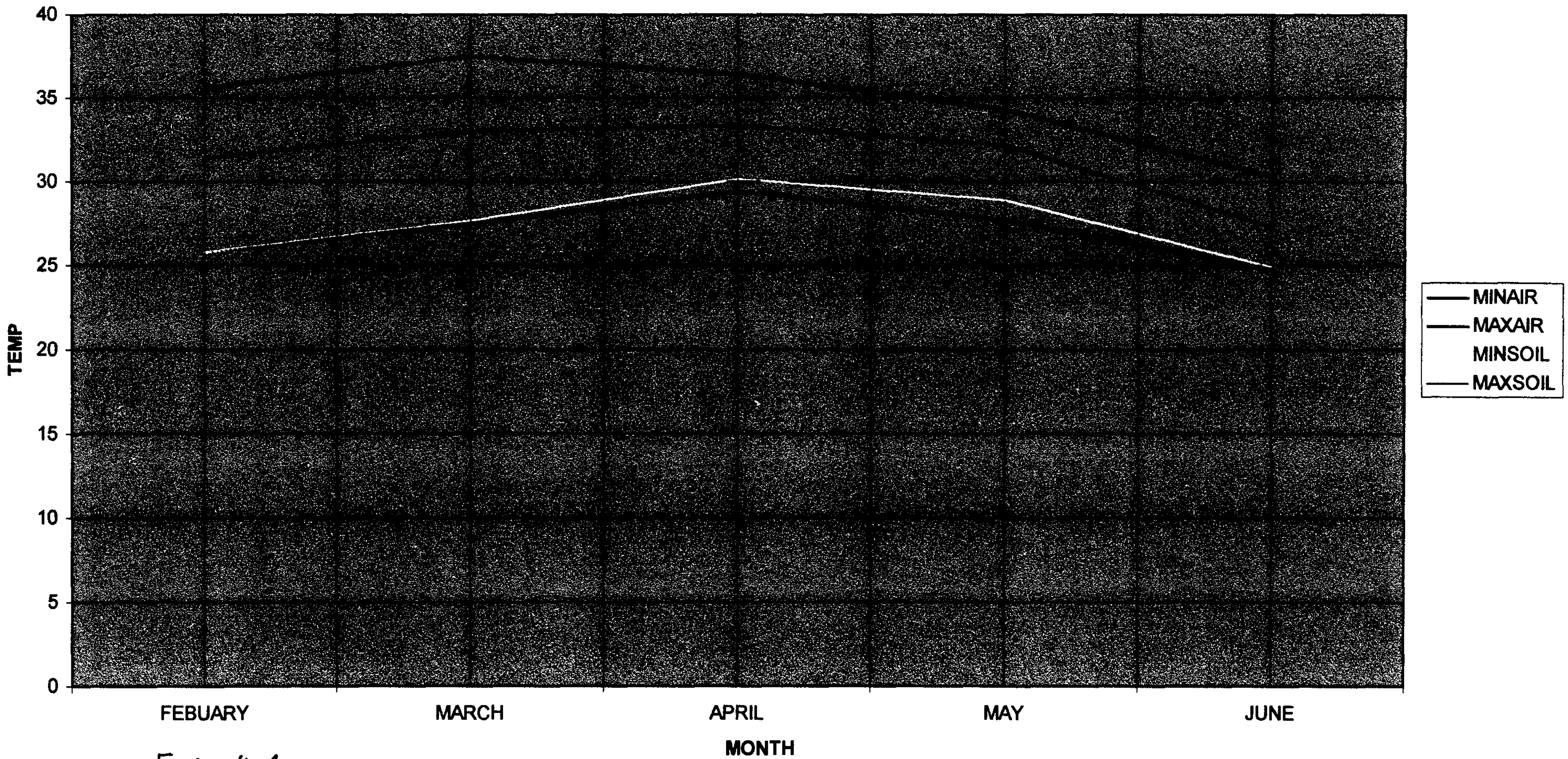


FIG. 4.4 MIN AND MAX AIR/SOIL TEMP. FOR PIT

29

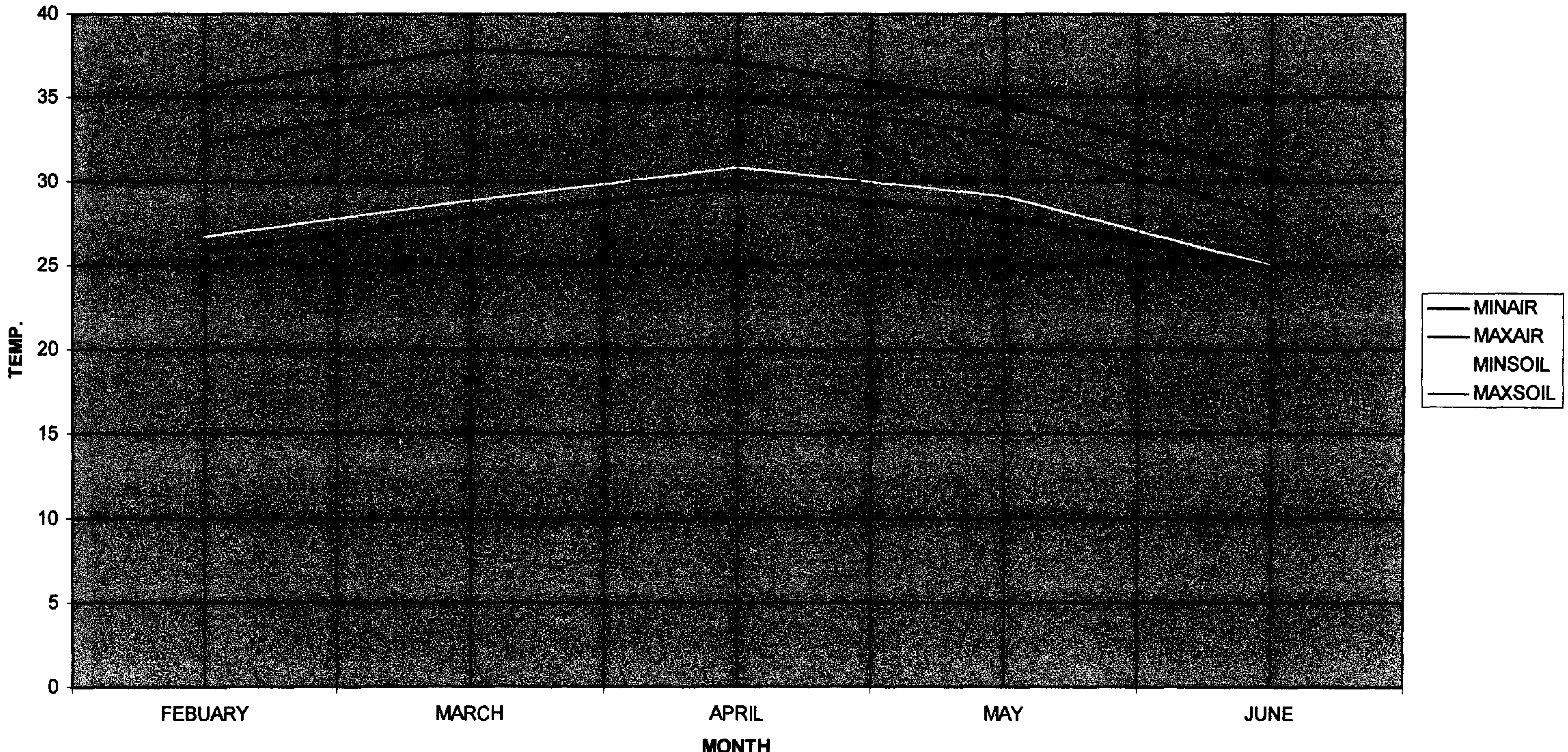


FIG 4.5 MIN AND MAX AIR/SOIL TEMP FOR LOCAL

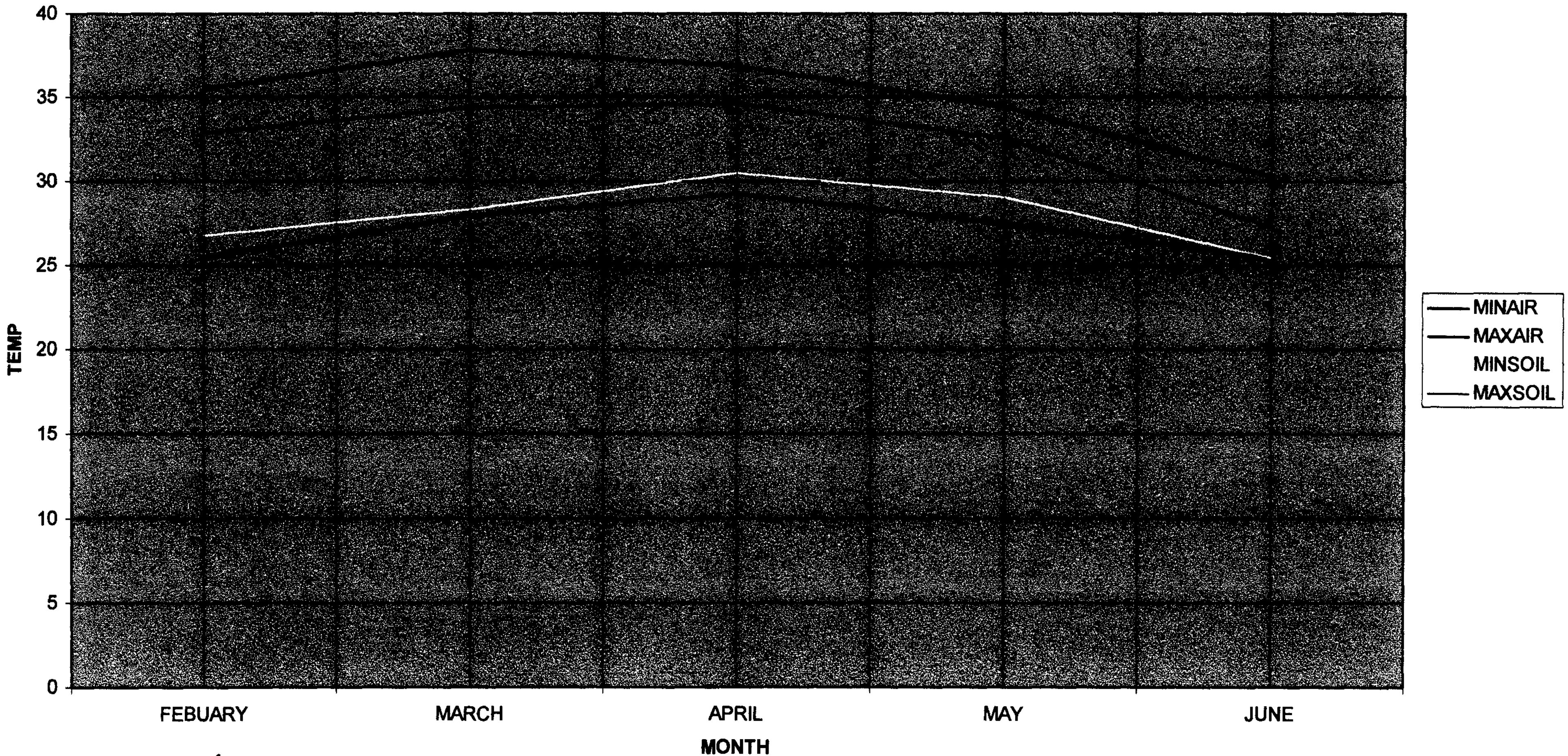


FIG 4.6 MIN AND MAX AIR/SOIL TEMP FOR IMPROVE

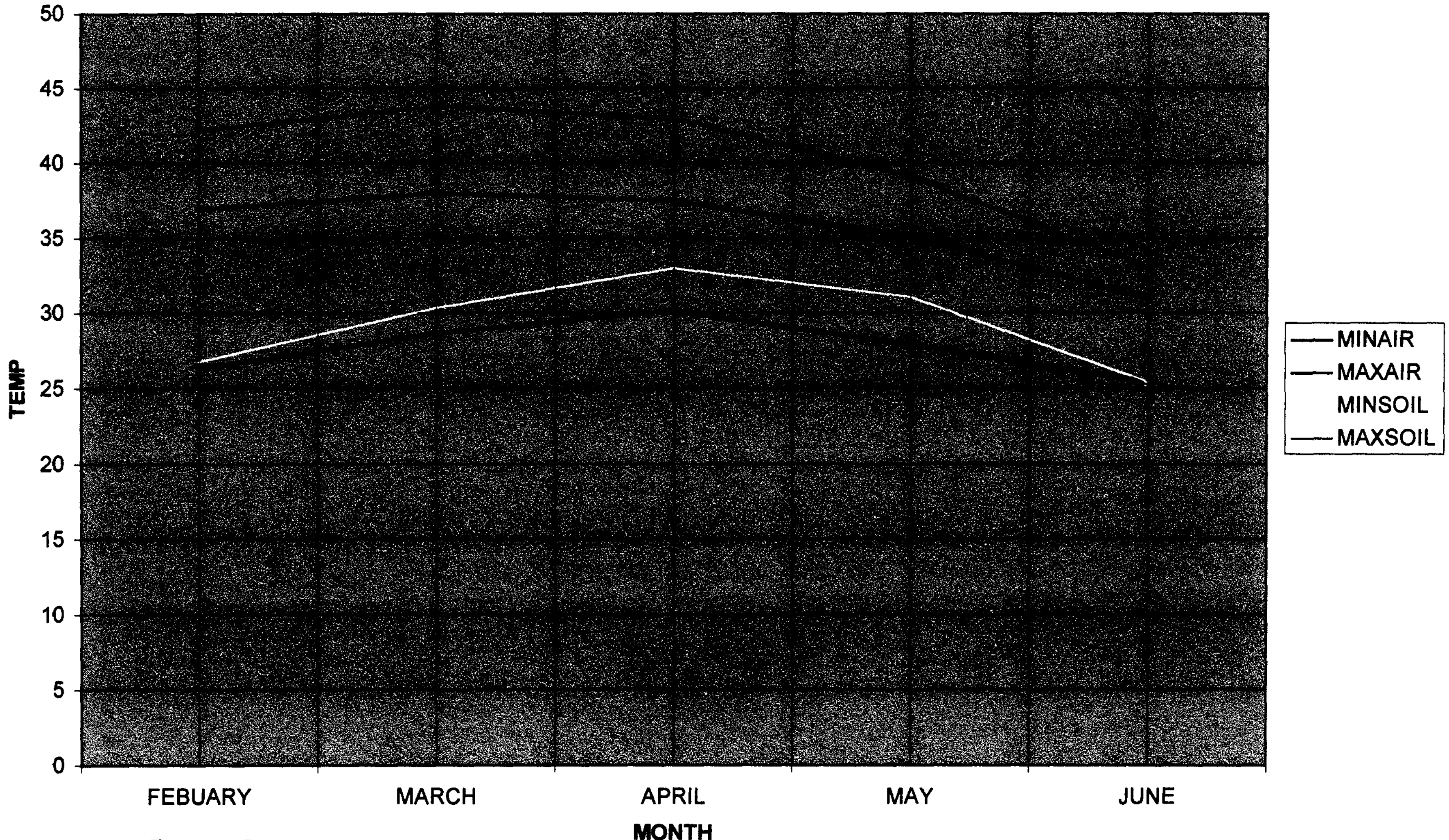


FIG 4.7 MIN AND MAX AIR/SOIL TEMP FOR OUTSIDE

4.1.2 DETERMINATION OF K1 AND K2 AND OTHER PARAMETERS.

Where q = heat transfer (W/MK)

λ = Thermal conductivity of the material (W/MK)

α = Heat transfer coefficient (W/M2K)

δ = Average thickness of the material (M)

t = Temperature at different surface (K)

K_1 = Overall heat transfer coefficient for pit and

Local storage barn (W/M2K)

K_2 = Overall heat transfer coefficient for

Improved storage barn (W/M2K).

Where K1 d = 0.025m

= 0.15W/MK

.,988 W/M2K

n = 2

α = 3

$= 1 / \sum_{i=1}^{i=n} x\lambda + \sum_{i=1}^{i=x} 1/\alpha i$

1/2(0.025)/ 0.15

+ 3 [1/(33.7988)]

= 1/0.333 + 0.08876

K1 =2.369W/m^{2}K

K2= $1 / \sum_{i=1}^{i=x} x\lambda + \sum_{i=1}^{i=n} 1/\alpha i$

Where δ_1 = 0.025M (Guinea corn stalk)

δ_2 = 0.100M (Rice straw)

λ_1 = 0.15W/M.K

λ_2 = 0.1184W/MK

α = 33.7988W/M2K

K2 = $1 / \sum \lambda/\delta + \sum 1/\alpha i$

Where λ=0.15w/mk

λ=0.1184w/mk

δ=0.025m (guinea corn stalk)

δ=0.10m (rice straw)

α=33.7988w/m^{2}K

1/[2(1/33.7988) +(0.025/0.15) +(0.100/0.1184)]

K2 = 0.961W/M2K

TABLE 4.17

AVERAGE MINIMUM AND MAXIMUM HEAT TRANSFER (qAV)

STRUCTURE PERIOD	PIT STORAGE BARN		LOCAL STORAGE BARN		IMPROVED STORAGE BARN	
	MINIMUM (W/MK)	MAXIM (W/MK)	MINIMUM (W/MK)	MAXIMUM (W/MK)	MINIMU (W/MK)	MAXIM (W/MK)
FEBURARY	1.337	2.973	1.1625	2.4473	0.788	1.369
MARCH	1.2529	2.912	0.3931	1.6838	0.147	0.168
APRIL	2.624	2.469	1.0234	1.2553	0.603	0.875
MAY	0.4527	2.074	0.157	1.363	0.315	0.689
JUNE	0.827	1.694	0.854	1.502	0.0288	0.634

NOTE:

qAv = K1(t1-t6)+ AE64TAV3(T1-T2)

K1 = 2.369w/m2k

A = 0.036m2 local barn, 0.02m2 pit barn.

6 = 5.73x10-8 3/m2k4

E = 0.82K2 = 0.1184 - W/M2K

4.1.4 DISCUSSION OF RESULT

Fig.4.1 show that pit storage barn has the lowest average minimum temperature throughout the storage period (February to June). This was caused by the fact that the walls constructed was reduced compared with others. And also the rate at which heat is been transfer through soil was very low as compared with other material used; not only that, when it rained there is downward movement of water this help to cool the surrounding within the pit. The figure also show that the improved barn follow pit in ascending order. This could be due to the used of rice straw which help to reduce the heat transfer rate either into or out of the barn and the highest of all the barn was local barn. This of course was due to the fact that there are more spaces between the stalk.

In all the outside minimum temperature was the highest and this indicating that there is a temperature reduction in all the three barns. Also, the figure show that the maximum temperature recorded throughout with outside having the highest, followed by local, improved, and pit having the least.

Fig.4.2 also show that throughout the storage period, pit storage has the least minimum soil temperature followed by the improved storage barn and also local with outside having the highest. This could be due to the fact that pit surface or platform falls below the ground level and also the downward movement or upward movement of water as the case may be help to maintain or to keep the soil surface or surrounding cooler then others.

That of barn when follow pit could be said to be as a result of enough protection provided by the lagging material which reduces heat transfer rate and also heat loss from the soil surface. In all outside has the highest, this is due to direct heat energy received from the solar. The figure also show that the maximum soil temperature increasing order, pit, improved, local and outside. The reasons for the minimum soil temperature also applicable here.

Fig.4.3 show that the percentage relative humidity both minimum and maximum is higher in all the three structure compared to the outside. This could be due to the temperature reduction in all the three structure compared to the outside and also due to the release of water (H20) from the tuber during respiration and transpiration. Among the barns pit has the highest pH followed by improved barn and local barn.

Fig.4.4, 4.5, 4.6 show that in all the barns minimum air temperature was lowered as compared with minimum soil temperature. Whereas, maximum air temperature is higher as compared with maximum soil temperature. This could be due to the fact that heat transfer rate through the air is faster and higher as compared with heat transfer phenomenon that is taken place on the soil surface. It also show that thermal conductivity of soil is lower for it takes longer time for it to loose or absorb heat from surrounding as compared with air which can easily absorb or loose heat.

As it was stated earlier, that the period of dormancy is affected or stopped when the stored tuber started sprouting.

PIT STORAGE

TABLE4:9 **RELATIVE HUMIDITY IN PERCENTAGE BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	21.27	15.8	18.48	22.48	15.8	22.48
MARCH A	17.48	12.76	12.63	14.96	12.63	17.48
MARCH B	48.08	34.27	33.04	27.56	23.04	48.08
APRIL A	61.89	45.07	40.38	52.83	40.38	61.89
APRIL B	66.35	41.29	37.48	45.5	37.48	66.35
MAY A	67.58	48.03	40.5	47.82	40.5	67.58
MAY B	72.38	60.56	60.5	69.05	60.5	72.38
JUNE	82.8	69.77	73.4	76.2	69.77	82.8

LOCAL STORAGE

TABLE4:10 **RELATIVE HUMIDITY IN PERCENTAGE BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	20.59	16.06	16.44	23.39	16.06	23.39
MARCH A	16.26	13.39	13.01	15.55	13.01	16.26
MARCH B	48.35	35.38	19.09	26.38	19.01	48.35
APRIL A	62.91	45.18	39.26	46.43	39.26	62.99
APRIL B	66.22	43.2	37.14	44.79	37.14	66.22
MAY A	67.64	48.34	40.55	46.61	40.55	67.64
MAY B	76.06	63.74	57.09	63.64	57.09	76.06
JUNE	75.43	69.03	69	77.3	69	77.3

IMPROVED STORAGE

TABLE4:11 **RELATIVE HUMIDITY IN PERCENTAGE BIWEEKLY**

MONTH	8:00AM	12:00NOO	4:00PM	7:00PM	MIN	MAX
FEBUARY	20.7	15.87	16.09	24.07	15.87	24.07
MARCH A	16.18	12.87	12.32	14.35	12.32	16.18
MARCH B	48.56	37.71	21.32	26.19	21.19	48.56
APRIL A	62.82	45.2	39.32	53.83	39.51	62.82
APRIL B	66.46	42.87	38.1	44.99	38.19	66.46
MAY A	67.47	48.3	40.1	46.4	40.2	67.47
MAY B	72.78	65.07	57.89	63.69	57.88	72.78
JUNE	78.1	70.21	69.13	76.77	69.13	78.1

The level of exposure of the yam to light and also the fluctuation in the air temperature of the barn play a great role at terminating the dormancy period of the stored yams.

Table 4.17 shows the average minimum and maximum heat transfer (qAV) in the three storage barn that was used for the experiment. The table show that the values, both minimum and maximum decreases from February to March in all the three barns that used. While the values both minimum and maximum rose up again in the month of April only to drop all through the subsequent months (May and June). These could be due to the changes in climatic condition from gradual increases in hot weather, which reach climate by April and proceeded with rainfall seasons, which account to drop in the values.

However, pit storage barn has the highest values all throughout the periods of storage. This was because there is a range of difference between the air temperature of the pit and that of the outsider. The pit has a cooling effect on the air temperature within the barn. Heat transfer rate besides other factors is also a function of temperature difference, in order to balance the difference heat is therefore transfer from region of higher temperature gradient to the lower temperature gradient. The nature of the material used for the construction also added to the overall effect of the heat transfer rate.

Local storage barn has the values next to that of pit, this is because the range of temperature difference between that of air temperature within the barn is closer to that of outside as compare with pit. The reason can also be linked to the material and the condition or nature of the structure walls.

Improved storage barn has the least heat transfer rate when compared with other storage barn apart from the temperature difference range which was closer, the lining of the structure with rice straw contributed to the reduction and this could be the reason while the improved storage barn has the least heat transfer rate throughout the period of storage.

CHAPTER FIVE

5.0.1 CONCLUSION

The work show the different method of heat transfer, heat energy was transferred into or out of the storage barn through the means of convection, conduction and radiation heat transfer. The rate of transfer was higher in the pit barn this was due to the wide difference between the outside and the inside of the structure. Pit was followed by the local storage barn and lastly the improved barn. In the case of relative humidity minimum and maximum value recorded are in ascending order of local, improved and pit. All these; Air temperature, soil temperature and relative humidity contributed to the self life of the stored yams.

5.0.2 RECOMMENDATION

In order to prolong the storage period, the temperature difference between the outside and inside throughout should be reduced. While the range of temperature difference between the minimum and maximum should be greatly reduced, this can only be achieved if the structure is properly lagged. I therefore recommend that the improved storage barn be use as a better alternative to store yam if properly lagged.

In order to avoid the tubers from absorbing water from the soil that can accelerate growth, a platform should be provided to placed the tubers on it.

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APPENDIX A

AVERAGE MINIMUM AND MAXIMUM HEAT TRANSFER LOCAL STORAGE BARN

The average minimum and maximum heat transfer is determined using the relationship.

qAv=K1 (t1-t6) + AEG4T3Av(T1-T2)

Where A = Area, 0.036M2

E = 0.82

6 = 5.73x10-83/M2K4

TAv= Average temperature

Using q = AEG4 TAv3 (T1-T2)

qA1 = 0.036x0.82x5.73x10-8(299.092)^3(299.32-298.864)x4

= 0.0825W/M.K

qA2 = 0.036x0.82x4x5.73x10-8x(309.44)^3 (309.94-308.942)

= 0.0789W/M.K

qB1 = 0.036x0.82x45.73x10-8x(301.062)^3 (301.113-301.011)

= 0.0188W/M.K

qB2 = 0.036 x 0.82x5.73x10-8x4x(310-95)^3 (311.03-310.877)

= 0.0311W/M.K

qc1 = 0.036x0.82x5.73x10-8x4x(302.929)^3 (303.175-302.684)

= 0.0923W/M.K

qc2 = 0.036x0.82x5.73x10-8x4 $(320.314)^3$ (310.513-310.115)

= 0.0804W/M.K

qD1 = 0.036x5.73x10-8x4$(300.89)^3$ (300.983-300.861)

= 0.022W/M.K

qD2 = 0.036x0.82x5.73x10-8x4 $(307.912)^3$ (308.177-307.646)

= 0.105W/M.K

qE1 = 0.036x0.82x5.73x10-8x4x $(298.33)^3$ (298.5-298.165)

= 0.060W/M.k

qE2 = 0.036x0.82x5.73x10-8x4x $(303.71)^3$ (304-303.413)

= 0.111W/m.k

LOCAL STORAGE BARN

Q = K1 (t1-t6)

K1 = 2.369W/M2K

qA1= 2.369 (299.32-298.864) = 1.08W/M.K

qA2 = 2.369 (309.94-308.942) = 2.369W/M.K

qB1 = 2.369 (301.713-301.077) = 1.663W/M.K

qB2 = 2.369 (311.03-310.877) = 0.362W/M.K

qc1 = 2.369 (303.175-302.684) = 1.163W/M.K

qc2 = 2.369 (310.513-310.115) = 0.943W/M.K

qD1 = 2.369 (300.938-300.861) = 0.135W/M.K

qD2 = 2.369 (308.177-307.646) = 1.258W/M.K

qE1 = 2.369 (298.5-298.165) = 0.794W/M.K

qE2 = 2.369 (304-303.413) = 1.391W/M.K

qAv = K1(t1-t6) + AEG4TAv3 (T1-T2)

qAv(A1) = 0.0825 + 1.08 = 1.1625W/M.K

qAv(A2) = 2.309 + 0.0783 = 2.447W/M.K

qAv(B1) = 1.665 + 0.0188 = 1.6838W/M.K

qAv(B2) = 0.362 + 0.0311 = 0.3931W/M.K

qAv(C1) = 1.163 + 0.0923 = 1.2553W/M.K

qAv(C2) = 0.943 + 0.0804 = 1.0234W/M.K

qAv(D1) = 0.125 + 0.022 = 0.157W/M.K

qAv(D2) = 1.258 + 0.105 = 1.363W/M.K

qAv(E1) = 0.794 + 0.060 = 0.854W/M.K

qAv(E2) = 1.391 + 0.111 = 1.502W/M.K

PIT STORAGE BARN

Q = AE64TAv3 (T1-T2)

Where E = 0.82

A = 0.02M2

6 = 5.73x10-8 3/m2k4

Jav = Average Temperature

QA1 = 0.02x0.82x5.73x10-8x4x(299.08)3(299.32-298.84)

= 0.024W/M.K

qA2 = 0.02x0.82x5.73x10-8x4x(309.11)3(309.94-308.685)

= 0,139W/M.K0

qB1 = 0.02x0.82x5.73x10-8x4 (301.124)3(301.713-300.535)

= 0.121W/MK

qB2 = 0.20x0.82x5.73x10-8x4 (310.77)3(311.03-310.525)

= 0.0569W/M.K

qc1 = 0.20x0.82x5.73x10-8x4x(303.175-302.455)

= 0.1752W/M.K

qc2 = 0.20x0.82x5.73x10-8x4x(309.98)3(310.513-309.455)

= 0.118W/M.K

qD1 = 0.20x0.82x5.73x10-8x4x (300.938-300.755)

= 0.0187W/M.K

qD2 = 0.20x0.82x5.73x10-8x4x (307.76)3 (308.177-307.34)

= 0.0917W/M.K

qE1 = 0.20x0.82x5.73x10-8x4x (298.33)3 (298.5-298.165)

= 0.033W/M.K

qE2 = 0.20x0.82x5.73x10-8x4x (303.66)3 (304-303.315)

= 0.072W/M.K

AVERAGE MINIMUM AND MAXIMUM HEAT TRANSFER PIT STORAGE BARN

Using K1 as the overall heat transfer coefficient

Q = K1 (t1-t6)

Where t1 = outside temperature

Tt = Inside temperature

K1 = Overall heat transfer coefficient

Q = heat transfer

K1 = 2.369W/M2K

qA1 = 2.369 (299.32-298.84) = 1.137W/M.K

qA2 = 2.369 (309.94-308.685) = 2.971W/M.k

qB1 = 2.369 (301.713-300.535) = 2.791W/M.K

qB2 = 2.369 (311.03-310.525) = 1.196W/M.K

qc1 = 2.369 (303.175 - 301.455) = 1.717W/M.K

qc2 = 2.369 (310.513-309.455) = 2.506W/M.K

qD1 = 2.369 (300.938-300.755) = 0.434W/M.K

qD2 = 2.369 (308.777-307.34) = 1.983W/M.K

qE1 = 2.369 (298.5 - 298.165) = 0.794W/M.K

qE2 = 2.369 (304-303.315) = 1.622W/M.K

qAc = K1(t1-t6) + AE64TAv3 (T1-T2)

qav(A1) 1.137 + 0.024 = 1.377W/MK

qAv(A2) = 2.921 + 0.0139 = 2.973W/MK

qAv(B1) = 2.791 + 0.121 = 2.912W/MK

qAv(B2) = 1.96 + 0.0569 = 1.2529W/MK

qAv(c1) = 1.717 + 0.752 = 2.4697W/MK

qAv(c2) = 2.506 + 0.118 = 2.624W/MK

qAv(D1) = 0.434 + 0.0187 = 0.457W/MK

qAv(D2) = 1.983 + 0.0917 = 2.074W/MK

qAv(E1) = 0.794 + 0.033 = 0.827W/MK

qAv(E2) = 1.622 + 0.072 = 1.694W/MK

IMPROVE STORAGE BARN

Q = K2(t1-t5)

K2 = 0.961W/M2K

qA1 = 0.961 (299.32-298.5) = 0.788W/MK

qA2 = 0.961 (309.94-308.515) = 1.369W/MK

qB1 = 0.961 (301.113 - 300.96) = 0.147W/MK

qB2 = 0.961 (311.03 - 310.855) = 0.168W/MK

qc1 = 0.691 (303.175-302.265) = 0.875W/MK

qc2 = 0.961 (310.513-309.88) = 0.603W/MK

qD1 = 0.961 (300.938 -300.61) = 0.315W/MK

qD2 = 0.961 (308.177-307.46) = 0.689W/MK

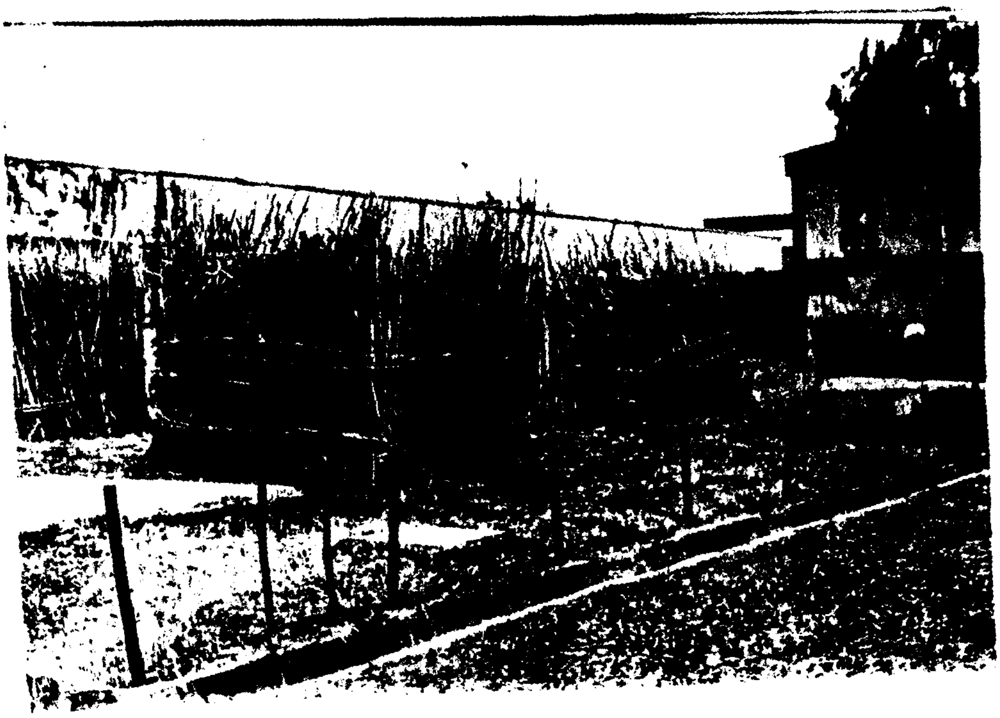
qE1 = 0.961 (298.5-298.47) = 0.0288W/MK

qE2 = 0.961 (304-303.34) = 0.634W/MK

TE 1: INTERIOR VIEW OF LOCAL STORAGE BARN.

GE BARN.

3: Interior view of pit storage barn



Exterior view of the storage barn; local, improved and pit