FACULTY OF ENGINEERING

DEPARTMENT OF AGRICULTURAL MECHANISATION AND IRRIGATION ENGINEERING

FINAL YEAR DESIGN PROJECT DISSERTATION

DESIGN AND CONSTRUCTION OF AN ELECTRIC AUTOMATIC GRAIN DRYER.

BY

NAME	REG. NO
WANDERA ELIJAH	BU/UP/2020/1996
APIA CHRISTINE	BU/UG/2020/1987

CASE STUDY: BUSIA DISTRICT

SUPERVISOR: ENG. SSAJA SSALI GODFREY

MR. MUYINGO EMMANUEL

FINAL YEAR PROJECT DESERTATION SUBMITTED IN PARTIAL FULFILLMENT FOR

THE AWARD OF BACHELOR OF SCIENCE IN AGRICULTURAL MECHANIZATION AND IRRIGATION ENGINEERING.

21 ST MAY, 2024

DECLARATION

We solemnly declare that this report is entirely owned by us. It has never been submitted to any university for the award in agricultural mechanization and irrigation engineering. We take full responsibility of it, and any other person mentioned here is not answerable.

Wandera Elijah signature: …………………………………………….

Apia Christine signature: ……………………………………………

03/07/2024

Date: ……………………………………………………………….

APPROVAL

This is to certify that this project dissertation was written by Mr. Wandera Elijah and Miss Apia Christine in fulfillment of research as part of their academic processes under supervision.

Supervisor

Name...MR. MUYINGO EMMANUEL...

Signature.....

Date...03/07/2024..

DEDICATION

This project dissertation is dedicated first to the Almighty God because by his grace, we have been able to come from far in all my academic process and secondly onto our beloved parents for their efforts, financially and other things towards our education and also our fellow friends whom have been around us.

Table of Content

DECLARATION i

APPROVAL ii

DEDICATION iii

LIST OF TABLES vii

1.0 CHAPTER ONE 1

1.1 INTRODUCTION 1

1.2 BACKGROUND 2

1.3 PROBLEM STATEMENT 3

1.3.1 INTERVENTION 3

1.4 OBJECTIVES 3

1.4.1 MAIN OBJECTIVE 3

1.4.2 SPECIFIC OBJECTIVES 3

1.5 Significance of study 3

1.6 Scope of the study 3

1.7 Justification 3

2.0 CHAPTER TWO 4

2.1 LITERATURE REVIEW 4

HARVESTING 5

Aflatoxin contamination of Maize grain and ground guts in Uganda 7

Review of the existing Grain drying systems 8

Artificial drying system 12

Typical resistance to airflow (Pa) per meter of crop depth 14

2.1.1 METHODOLOGY 17

2.1.2 The design of the machine 17

2.1.3 Automation control 17

2.2 Specific objective one: To design the different components of an Electric Automatic grain dryer 18

2.2.1 The drying chamber frame 18

2.2.2 Determination of Bulk density of harvested Maize 19

2.2.3 Amount of Moisture to be removed 19

2.2.4 Quantity of air required to Effect Drying, Q_a 19

2.2.6 Quantity of Heat Required for Effective Drying, Hr 19

2.2.7 Actual heat used to effect Drying, kJ ... 20
2.2.8 Energy required per hour, Q_t ... 20
2.2.9 Volume flow rate require to effect drying, $\dot{V}$ ... 20
2.3 Mass flow rate of drying air, M_f ... 20
2.3.1 Design of the paddles ... 20
2.3.2 Weight of the paddles ... 20
2.3.3 Angular velocity of paddles, V ... 21
2.3.4 Centrifugal force exerted by the paddles, $\boldsymbol{Fc}$ ... 21
2.3.5 The Hopper ... 21
2.3.6 Angle of repose ... 21
2.3.7 Design of the power transmission systems ... 21
2.3.8 The torque transmitted by the shaft ... 22
2.3.9 The design of the shaft ... 22
The diameter of the shaft ... 22
2.4.1 Power required by the motor ... 23
2.4.2 The factor of safety for the safety ... 23
2.4.3 The blower design and capacity ... 23
2.4.4 Heat transfer rate ... 23
2.4.5 Heating element design and capacity ... 24
2.4.6 Rate of mass transfer, $\boldsymbol{Qmtr}$ ... 24
3.0 Specific objective two ... 24
3.1 To fabricate and assemble the different components of the machine. ... 24
3.2 Specific objective three ... 25
3.2.1 To test the performance of the prototype. ... 25
3.3 Specific objective four ... 26
3.3.1 To carry out the financial analysis of the machine ... 26
3.3.2 Limitation of the study ... 27
CHAPTER 4 ... 28
RESULTS AND DISCUSSION ... 28
4.1 Determination of Bulk density of harvested Maize ... 29
4.1.1 Drying chamber design ... 29
4.2 Amount of Moisture to be removed ... 29
5.0 Quantity of air required to Effect Drying, Q_a ... 30

6.1 Volumetric flow rate 30
7.0 Blower design 31
8.0 Quantity of Heat Required for Effective Drying, Hr 31
8.1 Actual heat used to effect Drying, kJ 31
8.2 Energy required per hour, Q_t 32
8.3 Mass flow rate of drying air, M_f 32
8.3 heat transfer rate 32
9.0 Design of the paddles 33
9.1 Weight of the paddles 33
9.2 Determination of shaft speed 33
9.3 Angular velocity of paddles, V 33
9.4 Centrifugal force exerted by the paddles, Fc 33
9.4 Power and torque requirement 34
9.4.1 Power required for agitation of the grain 34
9.4.2 Torque required to agitate the maize grains 34
9.5 Design of the chimney 34
9.6 The Hopper 34
9.7 Angle of repose 35
9.8 Design of the power transmission systems 35
9.8.1 The design of the shaft 35
9.8.2 The diameter of the shaft 35
9.8.3 Maximum bending stress 36
9.8.3 Design stress, τ 36
9.8.4 Performance of the prototype. 36
9.8.4.1 The thermal efficiency 36
9.8.4.2 Drying rate of Maize grain, N 36
9.8.5 FINANCIAL ANALYSIS OF ELECTRIC AUTOMATIC GRAIN DRYER 37
9.8.5.1 initial investment of an electric Automatic grain dryer 37
9.8.5.2 Net present value (NPV) method 37
CHAPTER 5 41
5.0 CONCLUSIONS 41
5.1 RECOMMENDATION 41
5.2 Reference 42

5.3 APPENDICES 45

LIST OF TABLES

Table 1 show the Aflatoxin contamination in Maize and Ground nut in Eastern and Northern Uganda....... 8
Table 2 obtained from Taylor and Francis Group, LLC 8
Table 3 Airflow rates of different grains at different bed depth 14
Table 4shows the recommended values of Kb and Kt for different nature of load on shafts. 22
Table 5 shows the components and material selection criteria 24
Table 6 shows the tools, Equipment and Machines used 25
Table 7 minute variation in temperature of drying Chamber and Moisture content of Grain 28
Table 8 shows the Project Budget 37

List of figures

Figure 1 Shows Mature Maize Plant....5
Figure 2 Shows the Maize Kernel....6
Figure 3 shows the classification of grain dryers Diagram....9
Figure 4 shows the working principle of open Sun drying....10
Figure 5 Shows Maize Crib....10
Figure 6 shows direct solar dryer in passive mode....11
Figure 7shows indirect solar dryer in passive mode....11
Figure 8 shows mixed -mode Solar dryer....12
Figure 9 Shows principle of operation of active direct solar dryer....13
Figure 10 Deep-layer drying....14
Figure 11 Shows Recirculating batch bin dryer....15
Figure 12 shows Section showing the principle of a vertical shallow-layer batch dryer....15
Figure 13 Shows Continuous flow bin dryers....16
Figure 14 Working principles of a continuous-flow column dryer....16
Figure 15 shows the Automation system for Grain dryer....18
Figure 17 shows Elijah connecting power suppy to control system....45
Figure 18 show the system flow chart drawn from Edrawmax Software....45
Figure 19 show the prototype....45
Figure 20 shows Apia Christine grinding the grain inlet cover for grain dryer....46
Figure 21 shows Elijah cutting the piece of metal plate for making a hopper....46
Figure 22 shows the side view of the prototype....46
Figure 23 Shows the Orthographic Views of the Prototype....47
Figure 24 shows the on - line starter circuit for 4Hp three phase motor....49

LIST OF ABBREVIATIONS

FAO - Food and Agriculture Organization

LCD **-** Liquid crystal Display

CPU - Central Processing Unit

HP - Horse Power

PV - Present Value

NPV - Net Present Value

DC **-** direct current

UNBoS - Uganda National Bureau of Standards

Pbb – polyhalogenated biphenyl

ABSTRACT

Electric Automatic grain Dryer is designed to solve maize grain loss issues that emerge due to reliance on traditional grain drying methods such as open sun drying method. It is designed in such a way that moisture content and drying temperatures of grain are monitored and controlled by Arduino microcontroller. The machine is designed to dry 100kg of wet Maize per batch at initial moisture of 28%. It has the drying chamber of 60 cm in height and 60cm diameter.

The machine has cylindrical bin with two layers having cotton waste as an insulating material, slanting and perforated floor. And a shaft placed at the Centre of the cylinder with the spikes at alternate sides to each other serves as a stirrer that is driven by 4Hp three phase motor. In this dryer, grains are manually recharged into drying chamber.

The hot temperature needed to evaporate the water content in the grain for maximum results is in the range of 35^0C - 60^0C (Waqi'Ah & Raafi'U, 2023). Airflow plays an essential role in maintaining the relative humidity of the drying chamber. Low humidity will result in faster heat transfer.

The grain drying process requires heat transfer to evaporate the water contained in the grain. The air blown by the blower carry water vapor around it. The use of sensors allows the measurement of temperature, moisture content and relative humidity of the grain mass.

In addition, the Arduino controls the sequencing of blower motor and heat gun motor. Sensors that were used are temperature and moisture and they act as the input to the Arduino. The temperature sensor ensures that the grain's drying temperature doesn't exceed the prescribed limit. The moisture sensor measures the moisture content of the grain.

The controller (Arduino) gives the switching commands to blower, and heat gun through the sequential control program entered in memory of Arduino, by the user as per their requirement. After attaining the required final moisture content (about 13%), the controller stops the blowers and air heaters and turn on a buzzer to alert the farmer that grain is ready. However stirrer continues running for some time until when the grain cools and then it is manually stopped by farmer. The grains are collected and the new set of grains is put and then the process repeats.

1.0 CHAPTER ONE

1.1 INTRODUCTION

Maize (zea mays L.), is one of the major food crops in Uganda. Staple food crops in Uganda include matoke, beans, maize, cassava, sweet potatoes, sorghum and millet. However, Maize is a main stable food for many households in urban area, schools, military stations and hospitals. maize has a high value – that is to say 100gm of whole grain contains 10gm of protein and 4gm fat, and 360 calories; the germ (12% by weight of the whole grain) contains 22% of the total protein and 80% of the oil (Balirwa, 1992). It was introduced in Uganda in 1861 and by 1900, maize was already an established crop(Ministry of Agriculture, 1988). The World Bank estimated that there were about 1.3 million ha by 1992 (Balirwa, 1992). The commonest maize grain varieties that have been developed by the NARO are obatanpa, longe 1, 2, 3, 4, 5,5H, 6H, 9H, 10H, Longe 10, Longe 13, Longe 15, and Longe 17(National Agricultural Research Organisation, 2022).

Newly harvested maize, or grain, still has a lot of water content, around 24.89-34% (N. Of & Agriculture, 2014)(I. Of et al., n.d.). Before milling, must lower the moisture content of the grain, which is 13-15% on a dry basis. However, most farmers still use conventional methods for the grain drying process by drying it directly under the hot sun (Sihombing et al., 2019).

The process of drying grain conventionally, depends on climatic conditions, the area of land used can also affect the speed or duration of the drying process (Novrinaldi and S.A. Putra, 2019). According to (Müller et al., 2022), temperature and humidity cannot be controlled in an open room and grains can easily be contaminated with other impurities. This can worsen the quality of the dried grain. The drying time required for newly harvested maize in open sun, ranges from 10 to 20 days. However during the rainy season, the drying time can be longer than the 20 days, which might lead to the development of Aflatoxin–producing molds or fungi due to high moisture content and high relative humidity (85% which is the optimal relative humidity for Aflatoxin production(Kumar et al., 2021). Although high moisture content is one of the most significant factors for the Aflatoxin development, other factors also include plant stress due to competition of nutrient with weeds (Kinyungu, 2019), pH (1.7-9.3), High relative humidity (>85%), temperature (28 to 37^0 C)(Hawkins, L. K., Windham, G. L., & Williams, 2005). However, the development of the Aflatoxin leads to the loss of market value of the grain, cause liver cancer and low immunity especially in children. Therefore grain dryer required to address the above problems should be climate-independent and automatic.

There are many types of artificial grain dryers today, and the most commonly used by the public are bed dryers, rotary dryers, and vertical dryers. According to (M.A. Syarifuddin and L.O.M. Firman, 2018), the vertical drying type has a more even distribution of temperature and humidity reduction than different types of drying systems.

5.2 Reference

Agona, A. (2018). Post-harvest Management of Maize: A Review of Current Practices and Future Perspectives in Uganda. Uganda. *Journal of Agricultural Sciences*, *19*(1), 39–50.

Akello, J. (2021). *Maize Farming in Uganda: A Comprehensive Guide. AgriBiz.*

Ariong, R. M., Okello, D. M., Otim, M. H., & Paparu, P. (2023). The cost of inadequate postharvest management of pulse grain: Farmer losses due to handling and storage practices in Uganda. *Agriculture and Food Security*, *12*(1), 1–22. https://doi.org/10.1186/s40066-023-00423-7

Bakker Arkema, F.W., Debaerddomacker, P., A., M., Ruiz Altisent, Sltudman, C. Bakker Arkema, F. W., Debaerddomacker, P., Amirante, M., R. A. and, & Sltudman, C. (1999). *Handbook of Agriculture En_gineering. Reinhold Publishing Corporation*.

Balirwa, E. K. (1992). *Maize research and production in uganda*. *July*.

Bola, F. A., Bukola, A. F., & Olanrewaju, I. S. (2013). *Design parameters for a small- scale batch in-bin maize dryer*. *4*(5), 90–95. https://doi.org/10.4236/as.2013.45B017

Djaeni, M., Irfandy, F., & Utari, F. D. (2019). Drying rate and efficiency energy analysis of paddy drying using dehumidification with zeolite. *Journal of Physics: Conference Series*, *1295*(1). https://doi.org/10.1088/1742-6596/1295/1/012049

Ehiem, J. . (2008). *Design and development of an indus_trial fruit and vegetable dryer. An Unpublished M. Eng Thesis. Department of Agricultural and Environmental Engineering. University of Agriculture, Makurdi.*

Engineering, F. O. F. (2014). *B·usitema university*.

Hawkins, L. K., Windham, G. L., & Williams, W. P. (2005). Effect of different postharvest drying temperatures on Aspergillus flavus survival and aflatoxin content in five maize hybrids. Journal of Food Protection. *Food Protection*, *7*(68), 1521–1524.

Kiaya, V. (2014). Post-Harvest Losses and Strategies To. *The Journal of Agricultural Science*, *149*(3–4), 49–57. http://dx.doi.org/10.1016/j.jspr.2013.12.004%0Ahttp://www.journals.cambridge.org/abstract_S0021859610000936%0Ahttp://dx.doi.org/10.1016/j.worlddev.2014.08.002

Kinyungu, S. W. (2019). *Efficacy of pre-harvest Aspergillus flavus biocontrol treatment on reducing aflatoxin accumulation during drying. Doctoral dissertation, Purdue University Graduate School.*

Kumar, A., Pathak, H., Bhadauria, S., & Sudan, J. (2021). Aflatoxin contamination in food crops: causes, detection, and management: a review. *Food Production, Processing and Nutrition*, *3*(1). https://doi.org/10.1186/s43014-021-00064-y

Leung, L., & Jenkins, G. P. (2012). *A COST BENEFIT ANALYSIS OF MAIZE PRODUCTION AND MARKETING IN Acknowledgments*.

Little, A. (1984). *Abstract :*

M.A. Syarifuddin and L.O.M. Firman, J. M. T. D. S. (2018). No Title. *Ind.*, *2*(53).

Maize production. (2003).

Ministry of Agriculture. (1988). *Interim Research Report on Maize Soybean and Sunflower Field Trialsn, Entebbe,*.

Müller, A., Nunes, M. T., Maldaner, V., Coradi, P. C., Moraes, R. S. de, Martens, S., Leal, A. F., Pereira, V. F., & Marin, C. K. (2022). Rice Drying, Storage and Processing: Effects of Post-Harvest Operations on Grain Quality. *Rice Science*, *29*(1), 16–30. https://doi.org/10.1016/j.rsci.2021.12.002

National Agricultural Research Organisation, N. (2022). *Maize Varieties*.

Novrinaldi and S.A. Putra, J. R. T. (2019). No Title. *Ind.*, *13*(111).

Of, I., Air, D., On, T., & Breakage, M. G. (n.d.). *Influence of drying air temperature on maize grain breakage*. 409–414.

Of, N., & Agriculture, A. O. F. (2014). *U Niversity of S Zeged F Aculty of Agriculture Crop Production T Amás M Onostori*.

Onifade, T. B., Taiwo, A., & Jekayinfa, S. O. (2016). *Modification of A Locally Made Electric Crop Dryer Modification of A Locally Made Electric Crop Dryer*. *December 2017*.

otim, M., Gudu, S., Ogenga-Latigo, M. W., & Kidoido, M. (2019). Performance of drought-tolerant maize varieties under different agro-ecologies in Uganda. *International Journal of Climate Change Strategies and Management*, *2*(11), 249-262.

Sihombing, D., Arifin, Z., & Handayati, W. (2019). Study of rice cropping index increasing on dry land in Malang-East Java. *AIP Conference Proceedings*, *2120*. https://doi.org/10.1063/1.5115634

Singh, G., Jarial, R. K., Agarwal, A., Ram, S., Mondal, M., & Dogra, S. K. (2012). *Sequence Control of Grain Dryer Machine using PLC*. *3*(6), 34–40.

Tyler, H. G. (1985). *Standard handbook of engineering calculations. (2nd Edn.). McGraw-Hill Books Limited, New York.*

Vision, N. (2023). *Informal maize trade to blame farmers for market rejection*.

Waqi'Ah, S., & Raafi'U, B. (2023). Design and development automatic grain drying machine as an effort to improve the quality and selling price of rice. *AIP Conference Proceedings*, *2580*. https://doi.org/10.1063/5.0124357

Yenge, G., Phule, M., Vidyapeeth, K., Kad, V. P., Phule, M., Vidyapeeth, K., & Nalawade, S. (2018). *Physical Properties of Maize (Zea mays L .) Grain*. *January*, 3–7. https://doi.org/10.5958/2349-4433.2018.00173.3