

**DECISION SUPPORT SYSTEM FOR SIZING DRYING BINS, FAN  
SELECTION AND DRYING PARAMETERS DETERMINATION FOR  
SELECTED GRAINS**

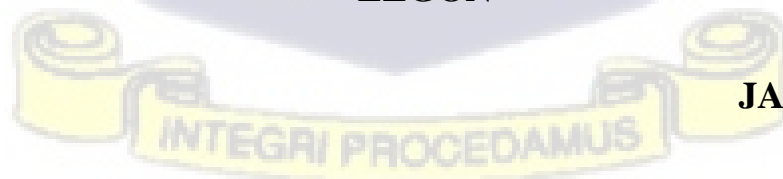
**BY**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA,  
LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT  
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UNIVERSITY OF GHANA  
LEGON**



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## DECLARATION

I, CEDRIC KPAKPO PARKER-ALLOTEY, author and conductor of this project do hereby declare that this work, except for references cited, was done entirely by me at the University of Ghana from JUNE 2021 to JANUARY 2022, under the supervision of PROF. RICHARD J. BANI and DR. EMMANUEL ESSIEN.

This work has never been presented either in whole or in part for any degree of the University of Ghana or elsewhere.

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## DEDICATION

This project is dedicated to God Almighty, my Lord and Saviour, my mother, Fanny Brown, and late father, Seth Parker-Allotey.



## ACKNOWLEDGEMENTS

First, I will exalt the Name of the Almighty God, my Master, Redeemer, and Friend. It is by His grace, strength, wisdom, and favour that I have been able to finish this project. To Him be all the Glory. I also thank Prof. Richard J. Bani and Dr. Emmanuel Essien, my project supervisors, whose guidance, and wisdom have been of immense help in completing this project. I am also indebted to Mr. Titus Anang, whose help has been massive. Lastly, I thank all who helped me in the undertaking of this project in one way or the other.



## ABSTRACT

Grain drying is a very important step in the storage and handling of grains. Computer models have been created over the past years to optimise and ease the amount of work and calculations that are invested into the planning, economics building, operation and management of drying systems and facilities. Although there have been advancements in computerised systems and programmes, decision making when it comes to planning, costing, construction, management, and operation of drying systems can still prove to be a strenuous task to undertake. Also, most computerised systems require in-depth knowledge in drying to operate. Most of these systems do not also provide features which allow for economic decision making. There is therefore still the need to develop a new programme which is relatively easier to use and can further optimise the decision-making process.

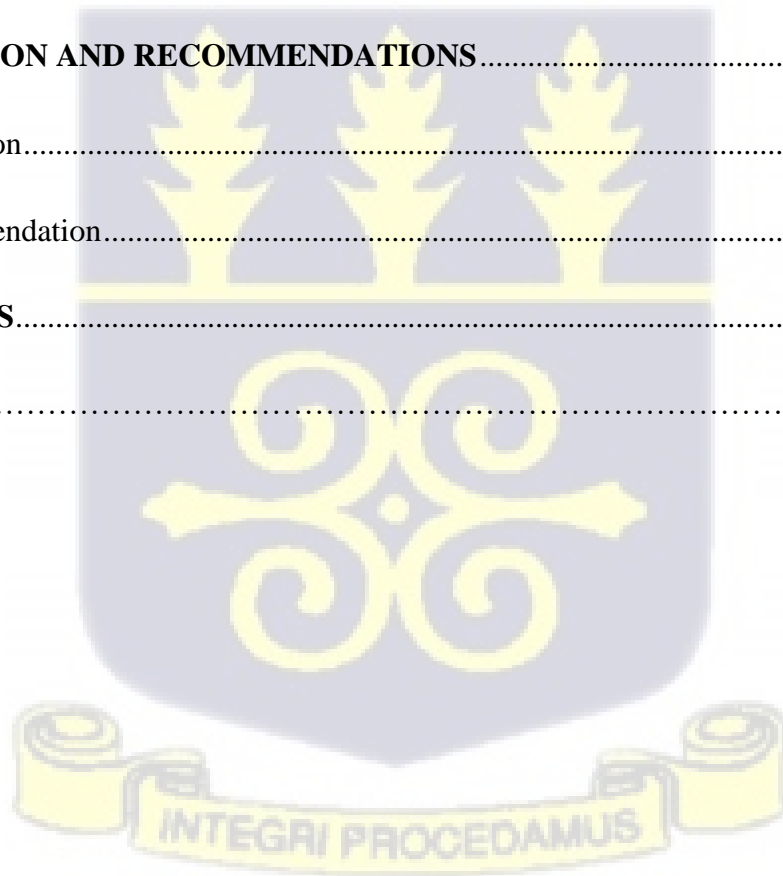
A computer programme was developed using python that calculates the bin diameter, grain depth, airflow and airflow rate, and fan horsepower using the specific grain to be dried, the desired volume, drying method, and budget type as inputs. Various formulas and assumptions were used to perform calculations for each parameter. The programme was created to provide realistic estimates for each drying parameter depending on the inputs provided by the user. The programme also provides a database that allows users to select fans based on the calculated fan horsepower.

The programme created was successful in performing calculations for all the parameters listed above. This programme simplified certain calculations that must be made during the decision-making process, thereby allowing for its use by people with shallow knowledge in drying systems decision making with respect to budgeting.

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## 1. INTRODUCTION

### 1.1 Background

Drying is defined as the removal of moisture from a material using heat (Basic Agricultural Study, 2020). In agriculture, commodities are dried for several reasons. Some of these reasons are to preserve the commodity by inhibiting bacterial growth as well as increasing shelf life (Kennedy, 2018), to decrease the size of commodities and make storage easier (Robbins, 2019), and to provide more prospects in processing.

Grain drying is a very important step in the storage and handling of grains. Liu *et al.* (2022) mentioned that the process of drying grains is a delicate heat and mass transfer process. Grains are normally dried and stored in round bins or flat storage systems. Drying of grains can be done using the following methods as listed by Loewer *et al.*, (1994): natural air drying, low temperature drying, layer drying, batch-in-bin drying, continuous flow drying, in-bin continuous flow drying, and combination drying. For the purposes of this project, low temperature drying, layer drying, and batch-in-bin drying will be defined.

In low temperature drying, a fan is used to push air through the grain to be dried. While the fan does this, the air is heated to a temperature of 10 °F (-12.22 °C) or lower. This heating is achieved with the use of an auxiliary heater, which is usually driven by electricity. Due to this, low temperature drying is sometimes referred to as electric drying (Sadaka *et al.*, 2017).

The working principle of layer drying is very similar to that of low temperature drying. The difference here, however, is that for layer drying, grains are loaded into the drying bin in layers. These layers are typically about four (4) to five (5) feet (1.2192 to 1.524 m) in depth. When drying begins with the first layer, a region of drying is set up, and makes its way through the grains (Hellevang, 1994).

According to Loewer *et al.*, (1994), batch-in-bin drying involves daily drying of a batch of grains in a drying bin at a usual depth of 2.5 to 4 ft (0.762 to 1.2192 m). After drying is done, the grains are cooled and loaded into storage bins prior to the next day's harvest.

Some examples of grains that are dried using these methods are maize, wheat, sorghum, soybean, and rice. Maier and Bakker-Arkema (2002) enunciate that the safe moisture contents required for storage of grains are dependent on the geographical site of storage, the amount of time the grain will spend in storage, the type of grain to be stored, and the storage facility to be used.

Computer models have been created over the past years to optimise and ease the amount of work and calculations that are invested into the planning, economics building, operation and management of drying systems and facilities.

Khatchatourian *et al.*, (2013) stated that mathematical modelling and computer simulations are extensively employed in the design of dryers and development of efficient grain drying control systems. Computer models make use of mathematical calculations and modelling to develop various solutions for specific drying problems or for the estimation and determination of various parameters needed to achieve specific drying needs. Computer models then create simulations based on these mathematical calculations and models to enable users make decisions, further calculations, and constructions.

Examples of computer programs created in past years are the FANMATCH and NATAIR models by Thompson (1975). The FANMATCH model calculates the horsepower requirements for a fan moving a specified volume of air per bushel of grain, and the NATAIR model estimates the time taken to dry the top layer of grain in natural air or low temperature drying configurations, for a desired or final moisture content.

Other examples include the CROSSFLOW model by Thompson *et al.*, (1968). This model predicts the drying rate and drying time, the amount of energy required to achieve drying, and the costs incurred when drying maize or grain sorghum.

The CACHE model (Loewer *et al.*, 1976) analyses the economics of owning a facility for the drying and storage of grains with or without feed processing. Other existing examples include LAYERD (Bridges *et al.*, 1982), CIRCLE (Loewer *et al.*, 1986), DUCT (Bridges *et al.*, 1988), and so on.

In recent years, several further advancements have been made in computer modelling for grain drying systems. Some of these new models are improvements of some of the earlier models mentioned above. Some models also make use of a combination of some of the models mentioned above to provide a wider range of operations and more effective and accurate simulations.

An example of such programmes is the LINSEC programme developed by Valente *et al.*, (2012), which incorporates the CROSSFLOW model by Thompson *et al.*, (1968) in its operation.

Another example of a recent advancement in computer modelling programmes for drying is the Ag Decision Maker developed by Edwards (2014). This model enables one to calculate and project the costs that will be incurred when drying corn, depending on the method of drying used.

While computer models may not be exactly accurate, in that they are mere simulations of what happens, they provide substantial data which when adjusted and used in real conditions, produce very accurate solutions to drying problems. Computer models allow for relatively easier decision making, since they take into consideration all the possible variables that play a

role in the drying process and develop optimal solutions for them. Some of these variables may be miscalculated, misplaced, or even forgotten due to human limitations and error. Computer models therefore help make management of drying facilities easier, draft accurate budgets, construct better structures, and devise more efficient drying operations when put in use.

## **1.2 Statement of Problem and Justification**

A lot of farmers in Ghana encounter problems when making decisions concerning drying of grains and drying operations in general. There are several parameters to be considered, and a lot of research to be done when making these decisions. Some of these parameters include the variety of grain to be dried, the type of drying method to be used, the cost of construction, operation and management of the drying facility, the equipment to be used, the energy requirements of the entire system, weather conditions of the geographical location where the drying facility is to be sited, the rate of airflow needed to dry a grain mass, the static pressures involved, and so on. This task can prove to be herculean and time consuming if one must undertake it without any form of computerised help, since there are several variables and constraints to be factored into the decision-making process. This may even lead to error, oversight, and the development of inefficient systems, if care is not taken.

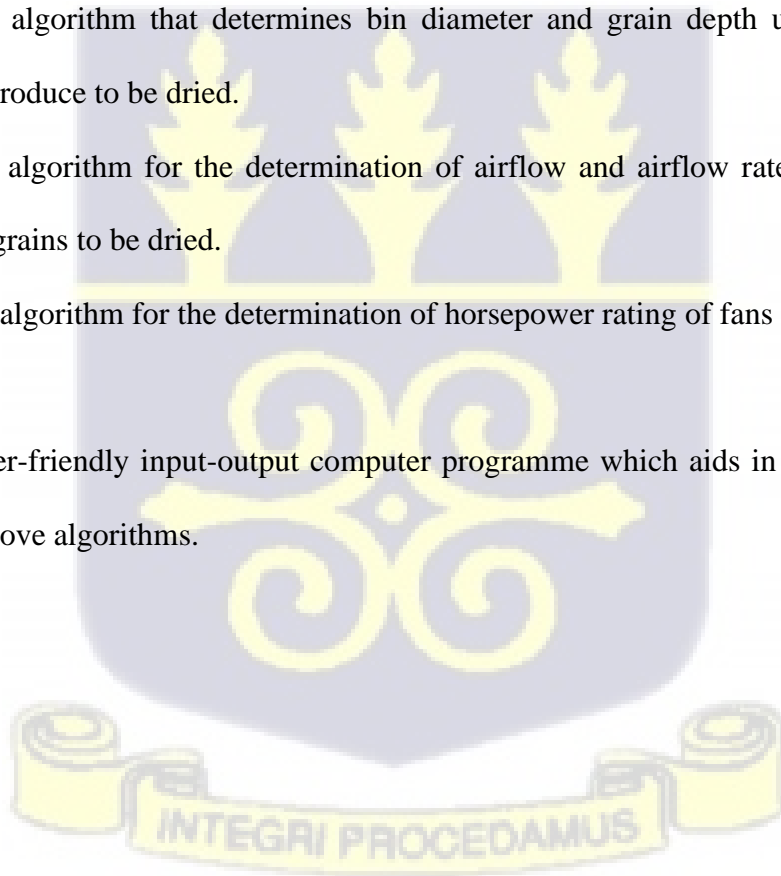
Although there have been advancements made in computerised systems and programmes, decision making when it comes to planning, costing, construction, management and operation of drying systems can still prove to be an arduous task to undertake. Also, most computerised systems require in-depth knowledge in drying to operate. Most of these systems do not also provide features which allow for economic decision making. There is therefore still the need to develop a new programme which is relatively easier to use and can further optimise the decision-making process. This programme therefore aimed to simplify certain calculations that

must be made during the decision-making process, thereby allowing for its use by people with shallow knowledge in drying systems. It also allows for decision making with respect to budgeting.

### 1.3 Objectives

The main objective of this project is to develop a decision support system which will aid in the sizing of round bins for drying, selection of drying fans, and estimation of energy requirements for low temperature drying, layer drying (deep bed and thin layer drying), and batch-in-bin drying of shelled corn, rough rice (paddy rice) and soybean. The specific objectives are as follows:

1. Develop an algorithm that determines bin diameter and grain depth using the desired volume of produce to be dried.
2. Develop an algorithm for the determination of airflow and airflow rate to be delivered against the grains to be dried.
3. Develop an algorithm for the determination of horsepower rating of fans to be selected for drying.
4. Create a user-friendly input-output computer programme which aids in decision making using the above algorithms.



## 2. LITERATURE REVIEW

### 2.1 Systems Analysis and Design

The word "systems analysis" refers to the study of real-world processes. It necessitates the dissection of problems into their constituent elements and the formulation of a conceptual understanding of the situation (Mason and Conger, 1994).

According to Ramakrishnan (2012), systems analysis and design (SAD) is a general word encompassing approaches for designing high-quality information systems that blend information technology, people, and data to satisfy business goals.

Rasmussen (2003) defines a system as a collection of interconnected components that work together to achieve a specific goal.

Shafaat and Kenley (2015) believe that as essential components of the outcomes for each intended option, systems analysis examines cost, schedule, risk, and other performance criteria. Modelling, activity-based costing, life cycle costing, levelling, life cycle analysis, data models, object-oriented modelling, event modelling, systems engineering, risk management, probabilistic modelling, financial modelling, design, and other well-known procedures that may have been used to consider a system from a particular perspective may all be included in systems analysis (Gregory, 2005).

Minder (1973) recounts that modern systems analysis was established in the computer field. Others, especially industrial engineers, found parallels between their own "efficiency" techniques and systems analysis, which they embraced and developed into non-computer fields. The study, design, assessment, and control of complex systems emerged from systems analysis. Engineers, however, limited its growth to the scientific approach. By the early 1960s systems analysis had evolved into an engineering field.

According to Pienaar (2011), however, systems analysis is widely considered to be inspired by operations research, which emerged at the start of World War II.

## **2.2 Systems Design and Engineering**

Faisander and Adcock (2021) define design as the process of constructing, expressing, recording, and conveying a system's layout through a comprehensive set of design features stated in a format that can be implemented.

Modelling, analysis, synthesis, and optimization are all part of the system design process (Sieniutycz, 2020).

According to Friedenthal *et al.*, (2015), systems engineering is an interdisciplinary approach to developing balanced system solutions that meet the varying needs of stakeholders. To achieve this balance and reduce risks that could jeopardize the project's success, systems engineering incorporates both managerial and technical processes.

## **2.3 Modelling and Simulation**

Gorinevsky (2005) stated that a mathematical conceptualisation (or representation) of a system is called a model. A system may be designed and analysed using models. Models are not entirely precise.

Simulation is the process of studying a dynamic behaviour of the system and predicting the effects of changes by utilizing computer-based models. Simulating complex systems is a useful tool for understanding, creating, and operating them. It's a tried-and-true technique to test new processes and ideas without having to spend money on costly new programs or models (Reynolds, 2018).

A computer can be used to create a mathematical model that contains important parameters of the physical system in modelling and simulation. The mathematical model is used to create a virtual representation of the physical system, and circumstances are applied to create the desired experiment. The simulation begins – that is, the computer determines the consequences of those conditions on the mathematical model, and produces results, according to the application.

## 2.4 Decision Support Systems

With the advancement of modelling and simulation technology over the years, decision making tools have been created to aid in estimation and calculation of various parameters, depending on the area of research or discipline. These decision-making tools are termed as Decision Support Systems (DSS). According to Jain and Raju (2016), a well-designed decision support system is an intuitive software-based system that assists decision makers in combining meaningful information from a variety of sources, including raw data, documents, personal knowledge, and business models, in order to ascertain and solve issues and make choices.

A DSS consists of some basic components. These components are outlined by Olavsrud (2020) as follows:

- **DSS Database:** It consists of data from within the company, data created by programs, and external data acquired from third parties or gathered from the internet. The DSS database will range in size from a small, stand-alone system to a big data warehouse, depending on the requirements.
- **DSS Software System:** The software system is based on a model that includes user objectives and decision scope. The quantity and types of models used in the DSS are determined by the goal of the DSS.

- **DSS User Interface:** Users can interact with and view outcomes using panels and other user interfaces.

Decision support systems have several benefits. Some of these benefits are documented by Alexander (2002):

- The ability of a decision maker to assimilate information and knowledge is enhanced by decision support systems.
- Decision support systems reduce the time it takes to make a choice.
- Decision support systems enhance the consistency of a decision-making process or result.
- They increase the capacity of the decision maker to handle large-scale, time-consuming, and complicated challenges.
- They motivate the decision-maker to experiment and acquire knowledge.

#### **2.4 Decision Support Systems Used for Grain Drying**

A MATLAB-based computer application has been created by researchers in the South Dakota State University (2021) with the aim of estimating drying performance in a continuous flow dryer. It allows the user to forecast a grain dryer's drying output for a variety of inbound corn moistures and dryer operation settings. The application processes systems of numerically relying algorithms based on the input and correlated partial differential equations describing the interaction of mass, energy, and moisture escape rates using a graphical user interface (GUI) that enables the user to readily define the required test criteria. The outputs include a series of graphical charts and estimated performance conditions for the drying column, including air temperature, grain temperature, and grain moisture content. Estimated drying time, drier throughput, and energy demands to dry the grain are added outputs. The application,

however, requires in-depth knowledge in drying systems to operate and interpret results. It also deals with only one crop (corn) and one drying method (continuous flow drying).

To simulate the operation of continuous flow grain dryers, a mathematical model and a computer software were created by Winik *et al.* (2013). Simulations were run for a variety of continuous flow dryer methods, including an energy-saving plan that recycles air for cooling and grain drying. The iterative technique was utilized to identify the starting conditions at the entry to each segment of the dryer. Computer simulations allowed for the evaluation of each system's energy efficiency, and the time of the drying process for geometry and the starting moisture content of the grains selected. This application, though efficient, also deals with just one drying method, making it limited in its use.

Courtois (1995) developed a Computer-Aided Design (CAD) software specially for French mixed-flow corn dryers, which also forecasts wet milling quality. For the software to work efficiently, some strategies were adopted at certain levels in the software. These strategies are listed below:

- Linkage of quality and drying models.
- An innovative steady-state integral approach that takes air recirculation and final moisture content enhancement into consideration.
- Limiting the number of equations using a compartmentalised method.
- For numerical integration, a novel adaptive-step approach has been developed.
- Assumptions to reduce the number of variables in equations.

This software also requires in-depth knowledge to operate.

Another decision support system worthy of note is the LINSEC programme developed by Valente *et al.* (2012). The programming language used for the development of this programme was Visual Basic 6.0. The goals of this programme were to utilise the Thompson model to

simulate high temperature drying of grains, establish a suitable language for the generation of drying models, and create a graphical user interface with the purpose of making it easier for users to appreciate. LINSEC was extremely useful for modelling and simulating drying systems, as well as generating simulated values that were quite near to reality. During the modelling of various types of dryers, LINSEC was extremely adaptable and user-friendly. This program, however does not allow decision making with respect to budgeting.

A grain bin volume calculator was created by the Institute of Agriculture and Natural Resources of the University of Nebraska – Lincoln (2017). The programme was written in HTML and calculates bin volume for both round and rectangular drying bins. For round bins, the calculator takes the radius and height of the bin to calculate the volume of grain the bin can hold. For rectangular bins, the inputs are the length, width, and height of the bin. All dimensions for the inputs are in feet (ft). The calculated volume of the bins is displayed in bushels. Figure 1 below shows the user interface of this programme:

**N** Institute of Agriculture and Natural Resources  
**CROPWATCH**

## Grain Bin Volume Calculator

NOVEMBER 16, 2017

**Calculate Grain Bin Capacity**

Shape  
Round ▼

Radius (feet)  
15

Height (feet)  
20

**Capacity:** 11,304 bushels

*Figure 1 - Grain bin volume calculator*

While this programme is relatively easy to use, it also does not provide features for economic decision making. It also requires internet access to use. This means that it cannot be used in locations without access to the internet.



### 3. MATERIALS AND METHODS

#### 3.1 Categorisation of Calculations

All calculations in this project were done according to three categories of budgets that the user may have: low, medium, and high budget. After the calculations have been done, the user can choose their preferred option. It is important to note that the results of these calculations are simulated values.

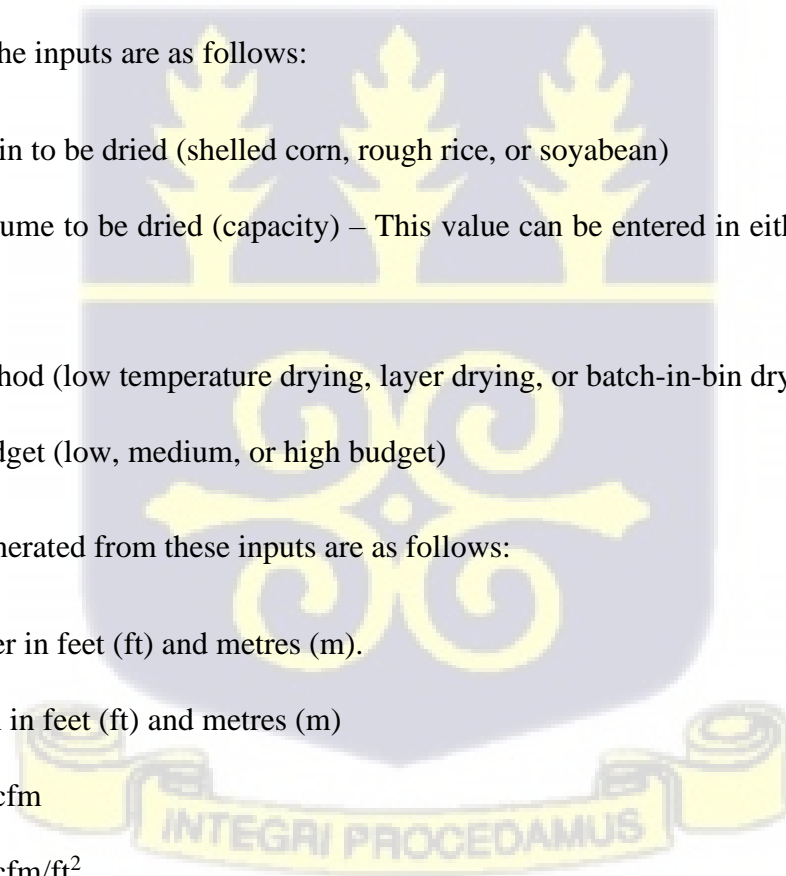
#### 3.2 Computer Programme and User Interface

A computer programme was written, and a user interface was designed in Python. With the required inputs, calculations will be done by the computer, and the results will be displayed on the interface. The inputs are as follows:

- Desired grain to be dried (shelled corn, rough rice, or soyabean)
- Desired volume to be dried (capacity) – This value can be entered in either metric tonnes or bushels
- Drying method (low temperature drying, layer drying, or batch-in-bin drying)
- Type of budget (low, medium, or high budget)

The outputs generated from these inputs are as follows:

- Bin diameter in feet (ft) and metres (m).
- Grain depth in feet (ft) and metres (m)
- Airflow in cfm
- Airflow in  $\text{cfm/ft}^2$
- Horsepower rating of the fan(s) to be used for drying



Based on the value of the calculated horsepower rating of the fan, one can select a fan from a compiled database of fans listed on the interface. The database was retrieved from the online fan selection tool created by Wilcke and Morey (2018).

### 3.3 Determination of Bin Diameter and Grain Depth

A database was created which consists of bushel capacities for round bins, with grain depths ranging from 0.5 ft (0.15 m) to 30 ft (9.14 m), with 0.5 ft increments, and bin diameters ranging from 15 ft (4.572 m) to 60 ft (18.288 m), with 3 ft (0.9144 m) increments, as computed by Loewer *et al.*, (1994). This database is based on the formula below:

$$\text{Capacity (bushels)} = \text{Bin volume} \times 0.8 \tag{1}$$

Where:

$$\text{Bin volume} = \pi r^2 h \text{ (ft}^3\text{)} \tag{2}$$

$$\text{radius of bin} = r = \frac{\text{bin diameter}}{2} \tag{3}$$

The desired volume to be dried can be entered in either bushels or metric tonnes (mt). All calculations were made in bushels. Due to this, when a value is inserted in metric tonnes, it is converted into bushels by multiplying the value by a conversion factor before further calculations take place. The conversion factors for each grain are listed in table 1 as follows:



**Table 1: Conversion factors for various grains**

<b>Grain</b>	<b>Conversion Factor</b>
Shelled Corn	39.368
Rough Rice	48.992
Soybean	36.7437

Also, when the desired volume is entered, the programme combs through the database and returns the corresponding bin diameter and grain depth. In cases where the desired volume is not found in the database, the programme returns values of the bin diameter and grain depth from the database that are closest to the exact value. These values are rounded up to the closest values found in the database. Hence it gives an estimate of the bin diameter and grain depth to be used for such a volume.

For example, if the desired volume entered is 100 bushels, the program will return a bin diameter of 18 ft and a height of 0.5 ft. In the database, the actual volume that corresponds to these returned values is 102 bushels but since 100 bushels is not in the database it returns the value for 102 bushels.

The program returns a value for the bin diameter in both feet and metres. All calculations in the programme were made in feet, therefore, to obtain values in metres, the values in feet are multiplied by 0.3048.



### 3.4 Determination of Airflow

The required total airflow (cfm) to be delivered by the fans for drying of the grain were determined by multiplying the volume of grain to be dried by the representative airflow rates for each grain drying method listed. The representative airflow rates (cfm/bu) were obtained from Loewer *et al.* (1994). They are listed in table 2 below:

**Table 2: Representative airflow rates for grain drying methods**

Drying Method	Range (cfm/bu)
Low Temperature Drying	1 - 3
Layer Drying	1 - 3
Batch-in-bin Drying	5 - 15

The formula for finding the total airflow (cfm) is shown below:

$$\text{Total airflow (cfm)} = \text{volume of grain} \times \text{representative airflow rate (cfm/bu)}$$

(Loewer *et al.*, 1994)

(4)

During the computation of these values for each drying method, the lowest value for each airflow range in cfm/bu was assumed for the low budget option, the middle value was assumed for the medium budget option, and the highest value for the high budget option.

For low temperature drying and layer drying, an airflow rate of 1 cfm/bu was assumed for the low budget option, 2 cfm/bu for the medium budget option, and 3 cfm/bu for the high budget option. For batch-in-bin drying, an airflow rate of 5 cfm/bu was assumed for the low budget option, 10 cfm/bu for the medium budget option, and 15 cfm/bu for the high budget option.

The airflow in  $\text{cfm}/\text{ft}^2$  was determined using the following formula:

$$\text{Airflow (cfm/ft}^2\text{)} = \text{grain depth} \times \text{airflow rate (cfm/bu)}/1.25 \text{ (Loewer et al., 1994)} \quad (5)$$

The same assumptions stated earlier were made for each calculation for the airflow in  $\text{cfm}/\text{ft}^2$ .

### 3.5 Determination of Horsepower Rating of Fans

Horsepower rating was determined using the formula by Sadaka (2013) below:

$$hp = \frac{\text{cfm} \times P_s}{3814} \quad (6)$$

Where:

cfm = airflow (cfm)

$P_s$  = static pressure (in.H<sub>2</sub>O)

Efficiency = fan efficiency

For calculation purposes, the efficiency of the fan will be assumed to be 60% as suggested by Wilcke and Morey (2018).

The static pressure,  $P_s$  was determined using the formula:

$$P_s = \text{Pressure drop (in. H}_2\text{O)} \times \text{grain depth} \times 1.5 \text{ (Loewer et al., 1994)} \quad (7)$$

1.5 is the packing factor.

The pressure drop,  $\Delta P$  was determined using the formula proposed by Kenghe *et al.* (2012):

$$\Delta P = \frac{AV^2}{\ln(1 + BV)} \quad (8)$$

Where:

$\Delta P$  = pressure drop, Pa or inches or water

A = constant for particular grain

B = constant for particular grain

V = airflow,  $\text{m}^3/\text{s} \cdot \text{m}^3$  or  $\text{cfm}/\text{ft}^2$

The values of A and B for each grain to be dried were obtained from a table compiled by ASABE (2009). They are listed in table 3 as follows:

**Table 3: A and B constants for various grains**

<b>Grain</b>	<b>Value of A (<math>\text{Pa} \cdot \text{s}^2/\text{m}^3</math>)</b>	<b>Value of B (<math>\text{m}^2 \cdot \text{s}/\text{m}^3</math>)</b>
Shelled corn	$2.07 \times 10^4$	30.4
Rough Rice	$2.57 \times 10^4$	13.2
Soyabean	$1.02 \times 10^4$	16.0

According to ASABE (2009), it is imperative to divide the above-mentioned A-values by 31635726 to get the equivalent values of A in inch-pound units ( $\text{in} \cdot \text{H}_2\text{O} \text{ min}^2/\text{ft}^3$ ). Divide the above-mentioned B-values by 196.85 to get matching values of B in inch-pound units ( $\text{ft}^2/\text{cfm}$ ).

After the horsepower rating is determined, the appropriate fan(s) can be selected from a drop-down menu consisting of various types of axial and centrifugal fans in the user interface. The fans in the menu start from horsepower ratings of 0.33 hp to 75 hp.

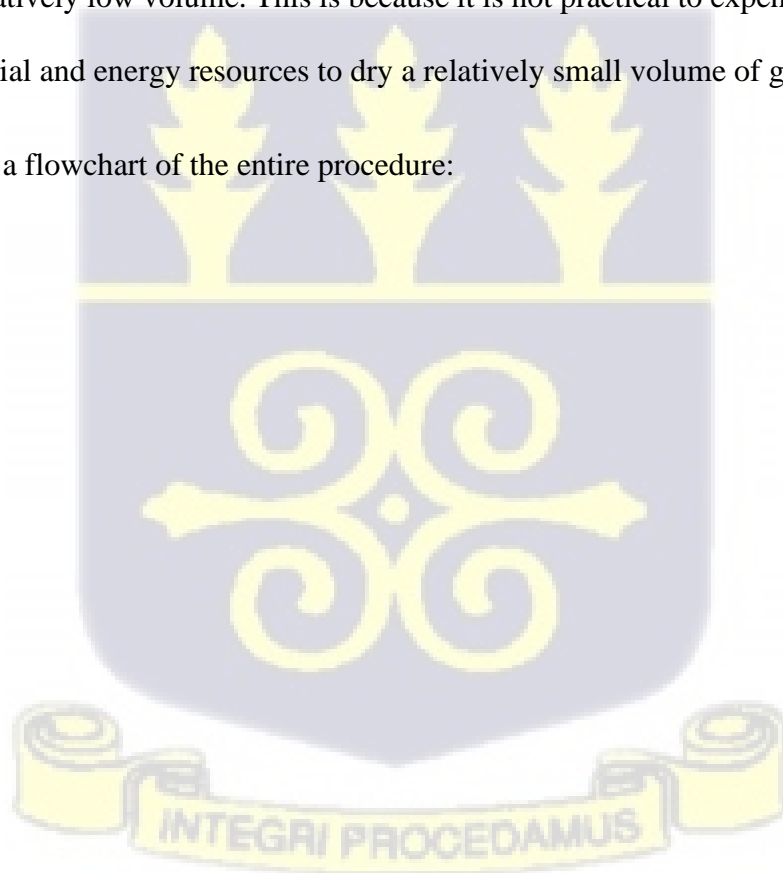
The calculated horsepower rating can be rounded up to the nearest horsepower rating found in the menu if it is not found in the menu. For example, a 10 hp fan is recommended if the calculated horsepower rating is 9.5 hp, since 9.5 hp is not found in the menu.

If the calculated horsepower rating for a particular fan is found in the menu, that fan can either be chosen, or the horsepower rating can be divided by any number the user decides on, if the user wishes to use multiple fans. In cases where the calculated horsepower is greater than what is found in the menu, it will be compulsory to divide the horsepower by a number (which will be decided on by the user) to obtain values that can be found in the menu. This means that in such cases, multiple fans are recommended.

For example, if the calculated horsepower is found to be 100 hp, the user can divide the value by two (2) to get two 50 hp fans, or four (4) to get four 25 hp fans.

In cases where a relatively small volume is entered (for example, 100 bushels), the calculated horsepower turns out to be much less than the lowest horsepower rating of the fans in the drop-down menu. The programme then notifies the user that it is not economically viable to dry grain due to relatively low volume. This is because it is not practical to expend relatively large financial, material and energy resources to dry a relatively small volume of grain.

Figure 2 shows a flowchart of the entire procedure:





*INTEGRI PROCEDAMUS*  
**Figure 2 - Drying DSS Flowchart**

#### 4. RESULTS AND DISCUSSION

After the programme was developed, five simulations were carried out on it to test its efficiency and accuracy in calculations. The programme was named “Drying DSS”, short for “Drying Decision Support System”. Below are the results for each simulation ran:

##### Simulation 1

The inputs for this simulation are outlined in Table 4 below:

**Table 4: Inputs for Simulation 1**

<b>Input</b>	<b>Value/Option</b>
Grain	Shelled Corn
Volume to be dried	100 tonnes
Drying method	Low temperature drying
Budget type	Low budget

The results the programme returned are shown in Table 5 below:

**Table 5: Outputs for Simulation 1**

<b>Output</b>	<b>Value</b>
Bin Diameter	21 ft / 6.40 m
Grain Depth	14.50 ft / 4.42 m
Airflow	3986.80 cfm
Airflow Rate	11.60 cfm / ft <sup>2</sup>
Horsepower Rating	0.31 hp

In the drop-down menu, a fan with a horsepower that is closest to the calculated horsepower can be selected. In this case, the appropriate fan is a **0.33 hp** fan.

## Simulation 2

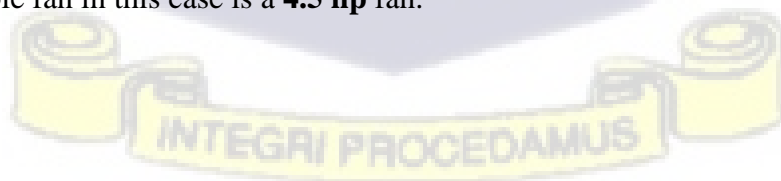
**Table 6: Inputs for Simulation 2**

Input	Value/Option
Grain	Rough Rice
Volume to be dried	150 tonnes
Drying method	Layer drying
Budget type	Medium budget

**Table 7: Outputs for Simulation 2**

Output	Value
Bin Diameter	30.00 ft / 9.14 m
Grain Depth	13.00 ft / 3.96 m
Airflow	14697.60 cfm
Airflow Rate	20.80 cfm / ft <sup>2</sup>
Horsepower Rating	3.48 hp

The most suitable fan in this case is a **4.5 hp** fan.



**Simulation 3**

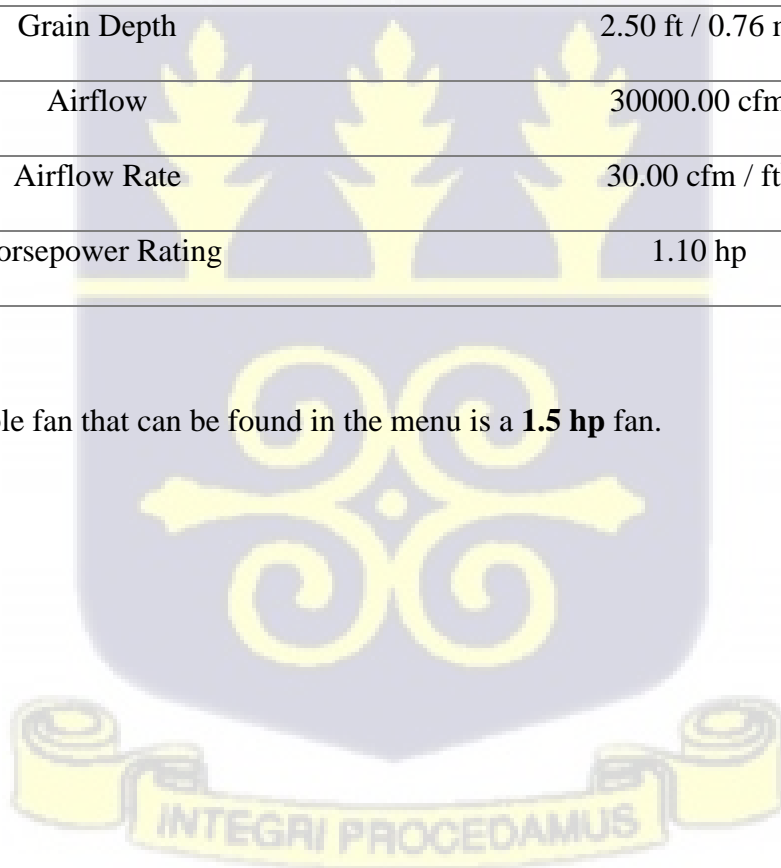
**Table 8: Inputs for Simulation 3**

<b>Input</b>	<b>Value/Option</b>
Grain	Soybeans
Volume to be dried	2000 Bushels
Drying method	Batch-in-bin drying
Budget type	High budget

**Table 9: Outputs for Simulation 3**

<b>Output</b>	<b>Value</b>
Bin Diameter	36.00 ft / 10.97 m
Grain Depth	2.50 ft / 0.76 m
Airflow	30000.00 cfm
Airflow Rate	30.00 cfm / ft <sup>2</sup>
Horsepower Rating	1.10 hp

The most suitable fan that can be found in the menu is a **1.5 hp** fan.



**Simulation 4**

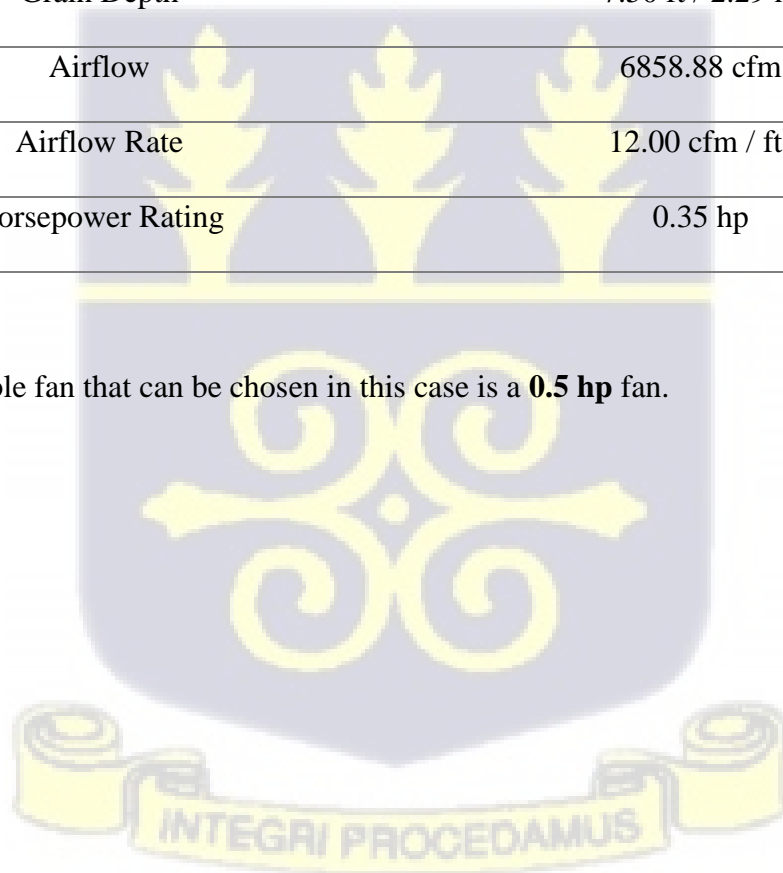
**Table 10: Inputs for Simulation 4**

<b>Input</b>	<b>Value/Option</b>
Grain	Rough Rice
Volume to be dried	70 tonnes
Drying method	Low temperature drying
Budget type	Medium budget

**Table 11: Outputs for Simulation 4**

<b>Output</b>	<b>Value</b>
Bin Diameter	27.00 ft / 8.23 m
Grain Depth	7.50 ft / 2.29 m
Airflow	6858.88 cfm
Airflow Rate	12.00 cfm / ft <sup>2</sup>
Horsepower Rating	0.35 hp

The most suitable fan that can be chosen in this case is a **0.5 hp** fan.



### Simulation 5

**Table 12: Inputs for Simulation 5**

Input	Value/Option
Grain	Shelled Corn
Volume to be dried	200 Bushels
Drying method	Layer Drying
Budget type	Low Budget

**Table 13: Outputs for Simulation 5**

Output	Value
Bin Diameter	18.00 ft / 5.49 m
Grain Depth	1.00 ft / 0.30 m
Airflow	200.00 cfm
Airflow Rate	0.80 cfm / ft <sup>2</sup>
Horsepower Rating	Not economically viable to dry grain due to relatively low volume.

In this case, the calculated horsepower is much less than the minimum horsepower rating in the dropdown menu due to the relatively small volume of grain to be dried, therefore the user is informed that it is not economically viable to dry that volume of grain.

The bin diameter and grain depth results for each simulation were compared with the grain bin volume calculator (University of Nebraska, 2017) and returned very similar values for the bin diameter and grain depth.

The results for the airflow and airflow rate were compared with the results of the airflow calculations carried out by Loewer *et al.* (1994). The values obtained for the simulations were the same as those of Loewer *et al.* (1994).

The results of the horsepower calculations carried out by the programme were congruent with the results of the calculations carried out by Wilcke and Morey (2018).

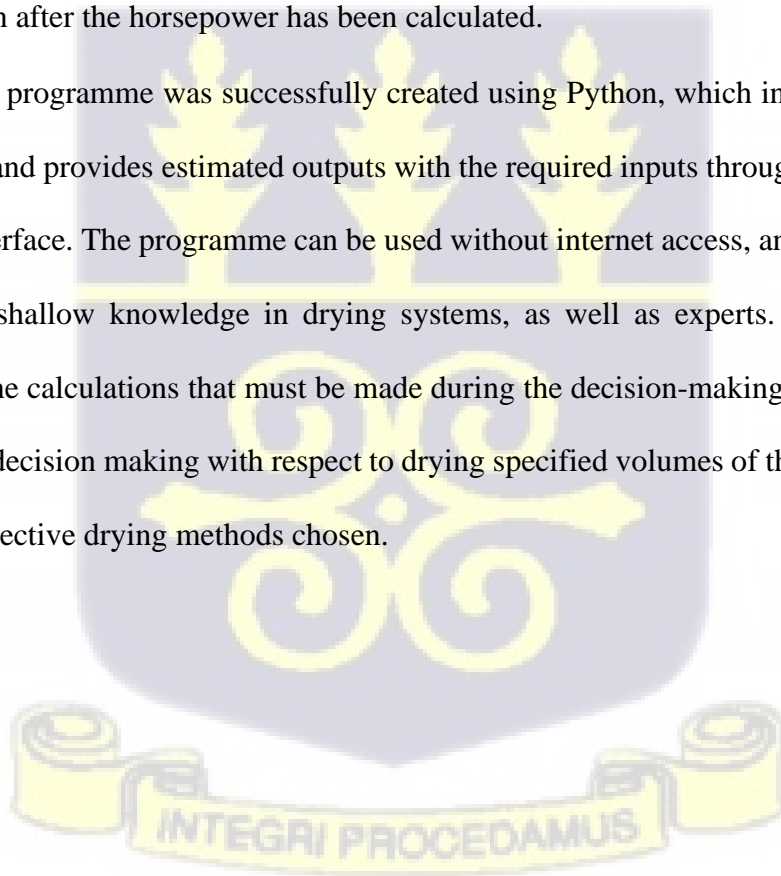


## 5. CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

The following conclusions are drawn from the study:

- An algorithm was successfully developed to determine the bin diameter and grain depth when the grain volume is entered, based on the formula given and the assumptions that were made.
- An algorithm was successfully developed to determine the airflow and airflow rates using the various formulas given and the assumptions made.
- The horsepower rating of the fans was successfully calculated using the formulas stated by the assumptions made in the study. A list of fans was also successfully compiled to aid in fan selection after the horsepower has been calculated.
- A computer programme was successfully created using Python, which integrates all these algorithms and provides estimated outputs with the required inputs through a simple, user-friendly interface. The programme can be used without internet access, and can be used by users with shallow knowledge in drying systems, as well as experts. The programme simplifies the calculations that must be made during the decision-making process, thereby optimising decision making with respect to drying specified volumes of the selected grains and the respective drying methods chosen.



## 5.2 Recommendations

The following recommendations are made:

1. Field tests should be run to determine specific values for some of the assumptions made during calculations to reduce the number of assumptions when improvements are being made to the programme.
2. Algorithms can be developed to determine other parameters such as drying temperature and drying time.
3. The programme can be further extended to accommodate more grains and drying methods.
4. A mobile application version can be created to enhance portability.



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## APPENDIX

### Python Code for Programme Development

#### Controller

```

from decimal import Decimal
import math

##### defining class for the controller of the application
class Compute(object):
    ##### initializing variables
    _bin_diameter = 0.00
    _grain_depth = 0.00

    _airflow_low = 0.00
    _airflow_medium = 0.00
    _airflow_high = 0.00

    _airflow_rate_low = 0.00
    _airflow_rate_medium = 0.00
    _airflow_rate_high = 0.00

    def __init__(self, crop='', capacity=0, capacity_format='tonnes',
drying_method='', budget=''):
        self._capacity_data = dict()
        self.crop = crop
        self.capacity = float(capacity)
        self.capacity_format = capacity_format
        self.drying_method = drying_method
        self.budget = budget

        self._generate_data()

    ### This function gerates a list containing all the bushel capacities with
their
    ### corresponding grain depths and bin diameters
    def _generate_data(self):
        grain_depth_data = [x*0.5 for x in range(1, 61)]
        bin_diameter_data = [x for x in range(15, 61, 3)]

        for b in bin_diameter_data:
            for g in grain_depth_data:
                capacity = math.pi * ((b / 2) ** 2) * g * 0.8
                value = f"{b},{g}"
                self._capacity_data[capacity] = value

```

```

def _calculate_capacity(self, multiplier) -> None:
    self.capacity = self.capacity * multiplier

##### this function converts the capacity from tonnes to bushels based on
the crop selected
def _convert_capacity(self) -> None:
    if self.capacity_format == 'tonnes':
        if self.crop == 'Shelled Corn':
            self._calculate_capacity(39.868)

        elif self.crop == 'Soybeans':
            self._calculate_capacity(36.7437)

        else:
            self._calculate_capacity(48.992)

##### this function finds the closest capacity to what the user desires
def _get_closest_capacity(self):
    capacities = self._capacity_data.keys()
    return min([v for v in capacities if v >= self.capacity] or [None])

##### this function calculate airflow and airflow rate needed to build the
drying system for various budget levels
def _calculate_air_flow(self) -> None:
    if self.drying_method in ('Low Temperature Drying', 'Layer Drying'):
        self._airflow_low = self.capacity * 1
        self._airflow_medium = self.capacity * 2
        self._airflow_high = self.capacity * 3

        self._airflow_rate_low = (self._grain_depth * 1) / 1.25
        self._airflow_rate_medium = (self._grain_depth * 2) / 1.25
        self._airflow_rate_high = (self._grain_depth * 3) / 1.25

    else:
        self._airflow_low = self.capacity * 5
        self._airflow_medium = self.capacity * 10
        self._airflow_high = self.capacity * 15

        self._airflow_rate_low = (self._grain_depth * 5) / 1.25
        self._airflow_rate_medium = (self._grain_depth * 10) / 1.25
        self._airflow_rate_high = (self._grain_depth * 15) / 1.25

##### function for calculating the static pressure based on crop selected
for various budget levels
def _static_pressure(self):
    crops = {
        'Shelled Corn': {
            'a': 2.07 * 10**4,

```

```

        'b': 30.4
    },
    'Soybeans': {
        'a': 1.02 * 10**4,
        'b': 16},
    'Rough Rice': {
        'a': 2.18 * 10**4,
        'b': 8.34
    }
}

a = crops[self.crop]['a'] / 31635726
b = crops[self.crop]['b'] / 196.85

if self.budget == 'Low budget':
    pressure = (a * self._airflow_rate_low**2) / math.log(1 + b *
self._airflow_low)
    static_pressure = pressure * self._grain_depth * 1.5

elif self.budget == 'Medium budget':
    pressure = (a * self._airflow_rate_medium**2) / math.log(1 + b *
self._airflow_medium)
    static_pressure = pressure * self._grain_depth * 1.5
else:
    pressure = (a * self._airflow_rate_high**2) / math.log(1 + b *
self._airflow_high)
    static_pressure = pressure * self._grain_depth * 1.5

return static_pressure

##### function to calculate the horsepower of the fans needed for drying
def _horse_power(self):
    if self.budget == 'Low budget':
        return (self._airflow_low * self._static_pressure()) / (63.46 *
60)

    elif self.budget == 'Medium budget':
        return (self._airflow_medium * self._static_pressure()) / (63.46 *
60)

    else:
        return (self._airflow_high * self._static_pressure()) / (63.46 *
60)

@staticmethod
def _to_string(value):
    return '{:.2f}'.format(value)

def _to_meters(self, ft):
    return self._to_string(ft*0.3048)

```

```

##### function to get the values of all calculated paremeters: bin
diameter, grain depth, airflow,
##### airflow rate and horsepower.
def get_calculated_data(self):
    self._convert_capacity()

    self._bin_diameter =
float(self._capacity_data[self._get_closet_capacity()].split(',')[0])
    self._grain_depth =
float(self._capacity_data[self._get_closet_capacity()].split(',')[1])

    self._calculate_air_flow()

    data = {
        'bin_diameter': {
            'ft': self._to_string(self._bin_diameter),
            'm': self._to_meters(self._bin_diameter)
        },

        'grain_depth': {
            'ft': self._to_string(self._grain_depth),
            'm': self._to_meters(self._grain_depth)
        }
    }

    if self.budget == 'Low budget':
        data['budget'] = {
            'airflow': self._to_string(self._airflow_low),
            'airflow_rate': self._to_string(self._airflow_rate_low),
        }
    elif self.budget == 'Medium budget':
        data['budget'] = {
            'airflow': self._to_string(self._airflow_medium),
            'airflow_rate': self._to_string(self._airflow_rate_medium),
        }
    else:
        data['budget'] = {
            'airflow': self._to_string(self._airflow_high),
            'airflow_rate': self._to_string(self._airflow_rate_high),
        }

    data['horse_power'] = self._to_string(self._horse_power())
##### A list of available fans and their horsepowers
data['horse_powers'] = [
    '0.33 hp AEROVENT 1240-DW | 12" (Axial)',
    '0.33 hp MFS 12" (Axial)',
    '0.33 hp ROLFES 5001-F (Axial)',

```

'0.5 hp FARM FANS 0512 SH | 12" 3450 rpm (Axial)',  
'0.75 hp BROCK 12" 3450 rpm (Axial)',  
'0.75 hp BUTTLER 12075 | 12" (Axial)',  
'0.75 hp CALDWELL F12.75 | 12" (Axial)',  
'0.75 hp CHICAGO 12" 3450 rpm (Axial)',  
'0.75 hp DMC 12" (Axial)',  
'0.75 hp GSI 12" (Axial)',  
'0.75 hp MFS 12" (Axial)',  
'0.75 hp MIDDLE STATE 12" 3450 rpm (Axial)',  
'0.75 hp NECO 12" (Axial)',  
'0.75 hp SCAFCO 12" (Axial)',  
'0.75 hp SUKUP 12" (Axial)',  
'1 hp AEROVENT 7-142-DW | 14" (Axial)',  
'1 hp BROCK 12" 3450 rpm (Axial)',  
'1 hp CALDWELL F14-1 | 14" (Axial)',  
'1 hp CHICAGO 13-1-102 (Axial)',  
'1 hp CHICAGO A14191F (Axial)',  
'1 hp DMC 12" (Axial)',  
'1 hp FARM FANS 114 SH | 14" 3450 rpm (Axial)',  
'1 hp GSI 12" (Axial)',  
'1 hp GSI 14" (Axial)',  
'1 hp MFS 14" (Axial)',  
'1 hp NECO 14" (Axial)',  
'1 hp ROLFES 5011-F (Axial)',  
'1 hp SUKUP 12" (Axial)',  
'1.5 hp AEROVENT 7-1880-DW | 18" (Axial)',  
'1.5 hp BROCK 14" 3450 rpm (Axial)',  
'1.5 hp BROCK 16" 3450 rpm (Axial)',  
'1.5 hp BUTLER 1415 | 14" (Axial)',  
'1.5 hp BUTLER 1815 | 18" (Axial)',  
'1.5 hp CALDWELL F18-1 | 18" (Axial)',  
'1.5 hp CALDWELL ILC18-1.5 | 3450 rpm (Centrif.)',  
'1.5 hp CHICAGO 14" 3450 rpm (Axial)',  
'1.5 hp CHICAGO 18" 3450 rpm (Axial)',  
'1.5-2 hp CHICAGO A18151F (Axial)',  
'1.5 hp DMC 18" (Axial)',  
'1.5 hp DMC 18" (Centrif.)',  
'1.5 hp DMC 18" InLineC (Centrif.)'  
'1.5 hp FARM FANS 116 AF | 16" 3450 rpm (Axial)'  
'1.5 hp FARM FANS 116 SH | 16" 3450 rpm (Axial)',  
'1.5 hp GSI 18" (Axial)',  
'1.5 hp GSI 18" (Centrif.)',  
'1.5 hp GSI 18" InLineC (Centrif.)',  
'1.5 hp MFS 16" (Axial)',  
'1.5 hp MFS 18" (Axial)',  
'1.5 hp MIDDLE STATE 12" 3450 rpm (Axial)',  
'1.5 hp MIDDLE STATE 14" 3450 rpm (Axial)',  
'1.5 hp MIDDLE STATE 16" 3450 rpm (Axial)',

'1.5 hp MIDDLE STATE 18" 3450 rpm (Axial)',  
'1.5 hp NECO 16" (Axial)',  
'1.5 hp SCAFCO 14" (Axial)',  
'1.5 hp SCAFCO 18" (Axial)',  
'1.5 hp SUKUP 14" (Axial)',  
'1.5 hp SUKUP 18" (Axial)',  
'1.5 hp SUKUP 18" In Line, 3450 rpm, 1-3 Ph(Centrif.)',  
'2 hp BROCK 18" 3450 rpm (Axial)',  
'2 hp BROCK 18" 3450 rpm InLineC (Centrif.)',  
'3 hp AEROVENT 7-18992-DW | 18" 3450 rpm (Axial)',  
'3 hp AEROVENT 7-3281-DW | 32" (Axial)',  
'3 hp BROCK 15" 3450 rpm (Centrif.)',  
'3 hp BROCK 18" 3450 rpm (Axial)',  
'3 hp BROCK 18" 3450 rpm InLineC (Centrif.)',  
'3 hp BROCK 22" 1750 rpm (Centrif.)',  
'3 hp BROCK 24" 3450 rpm InLineC (Centrif.)',  
'3hp BUTLER 1830 | 18" (Axial)',  
'3 hp BUTLER 2430 | 24" (Axial)',  
'3 hp CALDWELL CF15-3 | 3500 rpm (Centrif.)',  
'3 hp CALDWELL CF22-3 | 1750 rpm (Centrif.)',  
'3-4 hp CALDWELL F18-3 | 18" (Axial)',  
'3 hp CALDWELL ILC18-3 | 3450 rpm (Centrif.)',  
'3 hp CALDWELL ILC24-3 | 3450 rpm (Centrif.)',  
'3 hp CHICAGO 18" 3450 rpm (Axial)',  
'3-4 hp CHICAGO A18301F (Axial)',  
'3 hp DMC 18" (Axial)',  
'3 hp DMC 18" InLineC (Centrif.)',  
'3 hp DMC 24" InLineC (Centrif.)',  
'3 hp DMC CF-3 | 1750 rpm (Centrif.)',  
'3 hp DMC CHS-3 | 3500 rpm (Centrif.)',  
'3 hp FARM FANS 316 SH | 16" 3450 rpm (Axial)',  
'3 hp FARM FANS 318 AF | 18" 3450 rpm (Axial)',  
'3 hp GSI 18" InLineC (Centrif.)',  
'3 hp GSI 24" InLineC (Centrif.)',  
'3 hp GSI CF-3 | 1750 rpm (Centrif.)',  
'3 hp GSI CHS-3 | 3500 rpm (Centrif.)',  
'3 hp KEHO (Centrif.)',  
'3 hp MFS 18" (Axial)',  
'3 hp MIDDLE STATE 16" 3450 rpm (Axial)',  
'3 hp MIDDLE STATE 18" 3450 rpm (Axial)',  
'3 hp MIDDLE STATE MS 18-240 (Centrif.)',  
'3 hp NECO 18" (Axial)',  
'3 hp SCAFCO 18" (Axial)',  
'3 hp SCAFCO 24H1503, 3450 RPM (Centrif.)',  
'3 hp SCAFCO 24L2203, 1750 RPM (Centrif.)',  
'3 hp SUKUP 18" (Axial)',  
'3 hp SUKUP 3 hp, 1750 rpm (Centrif.)',  
'3 hp SUKUP 3-223 (Centrif.)',

'3 hp SUKUP 3-321 (Centrif.)',  
'3 hp SUKUP 3500 rpm (Centrif.)',  
'4.5 hp SUKUP 18" In Line, 3450 rpm, 1 Ph (Centrif.)',  
'4.5 hp SUKUP 18" In Line, 3500 rpm (Centrif.)',  
'5 hp AEROVENT 7-2490-DW | 24" (Axial)',  
'5 hp AEROVENT 7-3296-DW | 32" (Axial)',  
'5 hp AEROVENT 7-3613-DW | 36" (Axial)',  
'5 hp AEROVENT CD270-05 (Centrif.)',  
'5 hp BUTLER - (Centrif.)',  
'5 hp BUTLER 2450 | 24" (Axial)',  
'5 hp CALDWELL C24-51-53 | 1750 rpm (Centrif.)',  
'5 hp CALDWELL CF15-5 | 3450 rpm (Centrif.)',  
'5-7 hp CALDWELL F24-5 | 24" (Axial)',  
'5 hp CALDWELL ILC24-5 | 3450 rpm (Centrif.)',  
'5 hp CECO - (Centrif.)',  
'5 hp CECO - (Axial)',  
'5 hp CHICAGO 13-1-105 (Centrif.)',  
'5-7 hp CHICAGO BB501F & 503F | 22" (Axial)',  
'5 hp CIRCLE STEEL - (Centrif.)',  
'5 hp DMC 24" (Axial)',  
'5 hp DMC CF-5 | 1750 rpm (Centrif.)',  
'5 hp DMC CHS-5 | 3500 rpm (Centrif.)',  
'5 hp FARM FANS 524 SH | 24" (Axial)',  
'5 hp FARM FANS FFC-520B | 20" (Centrif.)',  
'5 hp FARM FANS FFCH-515E | 3500 rpm (Centrif.)',  
'5 hp GSI 24" (Axial)',  
'5 hp GSI CF-5 | 1750 rpm (Centrif.)',  
'5 hp GSI CHS-5 | 3500 rpm (Centrif.)',  
'5 hp KEHO (Centrif.)',  
'5 hp MFS 24" (Axial)',  
'5 hp MIDDLE STATE 18" 3450 rpm (Axial)',  
'5 hp MIDDLE STATE MS 18-240 (Centrif.)',  
'5 hp MIDDLE STATE MS 18-270 (Centrif.)',  
'5 hp MIDDLE STATE TF-5 | 24" (Axial)',  
'5-7 hp NECO 24" (Axial)',  
'5 hp NECO 27" (Centrif.)',  
'5 hp ROLFES (Centrif.)',  
'5 hp ROLFES (Axial)',  
'5 hp SCAFCO 24" (Axial)',  
'5 hp SCAFCO 24H1505, 3450 rpm (Centrif.)',  
'5 hp SCAFCO 24L2205, 1750 rpm (Centrif.)',  
'5-7 hp SUKUP 24" (Axial)',  
'5-7 hp SUKUP 24" In Line, 3450 rpm, 1-3 Ph (Centrif.)',  
'5-7 hp SUKUP 24" In Line, 3500 rpm (Centrif.)',  
'5 hp SUKUP 3500 rpm (Centrif.)',  
'5 hp SUKUP 5 hp, 1750 rpm (Centrif.)',  
'5 hp SUKUP 5-221 (Centrif.)',  
'5 hp SUKUP 5-223 (Centrif.)',

'7 hp CALDWELL CF18-7 | 3500 rpm (Centrif.)',  
'7 hp DMC 24" (Axial)',  
'7 hp DMC 24" InLineC (Centrif.)',  
'7 hp GSI 24" (Axial)',  
'7 hp GSI 24" InLineC (Centrif.)',  
'7-10 hp SUKUP 24" (Axial)',  
'7-10 hp SUKUP 24" In Line, 3500 rpm (Centrif.)',  
'7.2 hp AEROVENT 7-2491-DW | 24" 3450 rpm (Axial)',  
'7.2 hp AEROVENT 7-2710-DW | 27" (Axial)',  
'7.5 hp AEROVENT 7-2495-DW | 24" 3450 rpm (Axial)',  
'7.5 hp AEROVENT 7-3615-DW | 36" (Axial)',  
'7.5 hp AEROVENT 7-4260-DW | 42" (Axial)',  
'7.5 hp AEROVENT CD270-07 | 27" (Centrif.)',  
'7.5 hp BUTLER - (Centrif.)',  
'7.5 hp BUTLER 2475 | 24" (Axial)',  
'7.5 hp CALDWELL C24-71-73 | 1750 rpm (Centrif.)',  
'7.5-9.2 hp CALDWELL F24-7 | 24" (Axial)',  
'7.5 hp CALDWELL ILC28-7 | 3450 rpm (Centrif.)',  
'7.5 hp CECO - (Centrif.)',  
'7.5 hp CECO - (Axial)',  
'7.5 hp CHICAGO 13-1-106 (Centrif.)',  
'7.5-8.5 hp CHICAGO BB751F & 3F | 22" (Axial)',  
'7.5 hp CIRCLE STEEL - (Centrif.)',  
'7.5 hp DMC CF-7.5 | 1750 rpm (Centrif.)',  
'7.5 hp DMC CHS-7.5 | 3500 rpm (Centrif.)',  
'7.5 hp FARM FANS 724 SH | 24" (Axial)',  
'7.5 hp GSI CF-7.5 | 1750 rpm (Centrif.)',  
'7.5 hp GSI CHS-7.5 | 3500 rpm (Centrif.)',  
'7.5 hp KEHO (Centrif.)',  
'7.5 hp MFS 24" (Axial)',  
'7.5 hp MIDDLE STATE 18-240 (Centrif.)',  
'7.5 hp MIDDLE STATE MS 18-270 (Centrif.)',  
'7.5 hp MIDDLE STATE TF 75-1 | 24" (Axial)',  
'7.5-10 hp NECO 24" (Axial)',  
'7.5-10 hp NECO 26" (Axial)',  
'7.5 hp NECO 27" (Centrif.)',  
'7.5 hp ROLFES - (Centrif.)',  
'7.5 hp ROLFES - (Axial)',  
'7.5 hp SCAFCO 24" (Axial)',  
'7.5 hp SCAFCO 24H1507, 3450 rpm (Centrif.)',  
'7.5 hp SCAFCO 24L2207, 1750 rpm (Centrif.)',  
'7.5 hp SUKUP 3500 rpm (Centrif.)',  
'7.5 hp SUKUP 7.5 hp, 1750 rpm (Centrif.)',  
'7.5 hp SUKUP 7.5-241 (Centrif.)',  
'7.5 hp SUKUP 7.5-243 (Centrif.)',  
'9.3 hp AEROVENT 7-2722-DW | 27" 3450 rpm (Axial)',  
'9.5 hp MIDDLE STATE TF 95-1 | 24" (Axial)',  
'9.5 hp MIDDLE STATE TS 95-1 | 26" (Axial)',

'10 hp AEROVENT 7-2498-DW | 24" 3450 rpm (Axial)',  
 '10 hp AEROVENT 7-3692-DW | 36" 1725 rpm (Axial)',  
 '10 hp AEROVENT 7-4261-DW | 42" (Axial)',  
 '10 hp AEROVENT CD270-10 | 27" (Centrif.)',  
 '10 hp BEHLEN - (Centrif.)',  
 '10 hp BUTLER - (Centrif.)',  
 '10 hp BUTLER 27100 | 27" (Axial)',  
 '10 hp CALDWELL C18-103 | 3500 rpm (Centrif.)',  
 '10 hp CALDWELL C27-101-103 | 1750 rpm (Centrif.)',  
 '10 hp CALDWELL ILC28-10 | 3450 rpm (Centrif.)',  
 '10 hp CECO - (Centrif.)',  
 '10 hp CECO - (Axial)',  
 '10 hp CHICAGO BF1001 & 3 | 26" (Axial)',  
 '10 hp CHICAGO CF241001 & 3 (Centrif.)',  
 '10 hp CIRCLE STEEL - (Centrif.)',  
 '10 hp DMC 24" (Axial)',  
 '10 hp DMC 28" InLineC (Centrif.)',  
 '10 hp DMC CF-10 | 1750 rpm (Centrif.)',  
 '10 hp DMC CHS-10 | 3500 rpm (Centrif.)',  
 '10 hp FARM FANS 1028 SH | 28" (Axial)',  
 '10 hp FARM FANS FFC-1024B | 24" (Centrif.)',  
 '10 hp FARM FANS FFCH-1018E | 3500 rpm (Centrif.)',  
 '10 hp GSI 24" (Axial)',  
 '10 hp GSI 28" InLineC (Centrif.)',  
 '10 hp GSI CF-10 | 1750 rpm (Centrif.)',  
 '10 hp GSI CHS-10 | 3500 rpm (Centrif.)',  
 '10 hp KEHO (Centrif.)',  
 '10 hp MFS 28" (Axial)',  
 '10 hp MIDDLE STATE 18-240 (Centrif.)',  
 '10 hp MIDDLE STATE MS 18-270 (Centrif.)',  
 '10 hp NECO 27" (Centrif.)',  
 '10-15 hp NECO 28" (Axial)',  
 '10 hp ROLFES - (Centrif.)',  
 '10 hp ROLFES - (Axial)',  
 '10 hp SCAFCO 24H1810, 3450 rpm (Centrif.)',  
 '10 hp SCAFCO 24L2410, 1750 rpm (Centrif.)',  
 '10 hp SUKUP 10 hp, 1750 rpm (Centrif.)',  
 '10 hp SUKUP 10-271 (Centrif.)',  
 '10 hp SUKUP 10-273 (Centrif.)',  
 '10-15 hp SUKUP 28" (Axial)',  
 '10-15 hp SUKUP 28" In Line, 3450 rpm, 1-3 Ph (Centrif.)',  
 '10-15 hp SUKUP 28" In Line, 3500 rpm (Centrif.)',  
 '10 hp SUKUP 3500 rpm (Centrif.)',  
 '10.5 hp CALDWELL F24-10 | 24" (Axial)',  
 '12 hp CHICAGO - (Axial)',  
 '12.2 hp MIDDLE STATE TF 120-1 | 26" (Axial)',  
 '12.2 hp MIDDLE STATE TS 120-1 | 26" (Axial)',  
 '12.5 hp AEROVENT 7-2725-DW | 27" 3450 rpm (Axial)',

'12.5 hp CALDWELL F28-12 | 28" (Axial)',  
'13 hp SHIVERS 28" 13 hp (Axial)',  
'15 hp AEROVENT 7-4267-DW | 42" (Axial)',  
'15 hp AEROVENT CD270-15 | 27" (Centrif.)',  
'15 hp BUTLER - (Centrif.)',  
'15 hp CALDWELL C18-153 | 3500 rpm (Centrif.)',  
'15 hp CALDWELL C27-151-153 | 1750 rpm (Centrif.)',  
'15 hp CECO - (Centrif.)',  
'15 hp CHICAGO - (Centrif.)',  
'15 hp CIRCLE STEEL - (Centrif.)',  
'15 hp DMC 26" (Axial)',  
'15 hp DMC 28" (Axial)',  
'15 hp DMC 28" InLineC (Centrif.)',  
'15 hp DMC CF-15 | 1750 rpm (Centrif.)',  
'15 hp DMC CHS-15 | 3500 rpm (Centrif.)',  
'15 hp FARM FANS FFC-1524B | 24" (Centrif.)',  
'15 hp FARM FANS FFCH-1518E (Centrif.)',  
'15 hp GSI 26" (Axial)',  
'15 hp GSI 28" (Axial)',  
'15 hp GSI 28" InLineC (Centrif.)',  
'15 hp GSI CF-15 | 1750 rpm (Centrif.)',  
'15 hp GSI CHS-15 | 3500 rpm (Centrif.)',  
'15 hp KEHO (Centrif.)',  
'15 hp MIDDLE STATE 18-240 (Centrif.)',  
'15 hp MIDDLE STATE MS 18-270 (Centrif.)',  
'15 hp MIDDLE STATE MS 18-300 (Centrif.)',  
'15 hp NECO 27" (Centrif.)',  
'15 hp ROLFES - (Centrif.)',  
'15 hp SCAFCO 24H1815, 3450 rpm (Centrif.)',  
'15 hp SCAFCO 24L2715, 1750 rpm (Centrif.)',  
'15 hp SUKUP 15 hp, 1750 rpm (Centrif.)',  
'15 hp SUKUP 15-271 (Centrif.)',  
'15 hp SUKUP 15-273 (Centrif.)',  
'15 hp SUKUP 3500 rpm (Centrif.)',  
'15 hp SUKUP 38" (Axial)',  
'20 hp AEROVENT CD270-20 | 27" (Centrif.)',  
'20 hp BEHLEN - (Centrif.)',  
'20 hp BUTLER - (Centrif.)',  
'20 hp CALDWELL C30-203 | 1750 rpm (Centrif.)',  
'20 hp CALDWELL CF-22-20 | 3500 rpm (Centrif.)',  
'20 hp CECO - (Centrif.)',  
'20 hp CHICAGO CF272001 & 3 (Centrif.)',  
'20 hp CIRCLE STEEL - (Centrif.)',  
'20 hp DMC CF-20 | 1750 rpm (Centrif.)',  
'20 hp DMC CHS-20 | 3500 rpm (Centrif.)',  
'20 hp FARM FANS FFC-2027B | 27" (Centrif.)',  
'20 hp GSI CF-20 | 1750 rpm (Centrif.)',  
'20 hp GSI CHS-20 | 3500 rpm (Centrif.)',

'20 hp MIDDLE STATE MS 18-270 (Centrif.)',  
'20 hp MIDDLE STATE MS 18-300 (Centrif.)',  
'20 hp NECO 27" (Centrif.)',  
'20 hp ROLFES - (Centrif.)',  
'20 hp SCAFCO 24H1820, 3450 rpm (Centrif.)',  
'20 hp SCAFCO 24L2720, 1750 rpm (Centrif.)',  
'20 hp SUKUP 20 hp, 1750 rpm (Centrif.)',  
'20 hp SUKUP 20-301 (Centrif.)',  
'20 hp SUKUP 20-303 (Centrif.)',  
'20 hp SUKUP 3500 rpm (Centrif.)',  
'25 hp CALDWELL C30-253 | 1750 rpm (Centrif.)',  
'25 hp CALDWELL CF-22-25 | 3500 rpm (Centrif.)',  
'25 hp DMC CF-25 | 1750 rpm (Centrif.)',  
'25 hp FARM FANS FFC-2530A | 1750 rpm (Centrif.)',  
'25 hp GSI CF-25 | 1750 rpm (Centrif.)',  
'25 hp MIDDLE STATE MS 18-300 (Centrif.)',  
'25 hp MIDDLE STATE MS 18-330 (Centrif.)',  
'25 hp NECO 30" (Centrif.)',  
'25 hp SCAFCO 24H2225, 3450 rpm (Centrif.)',  
'25 hp SCAFCO 24L3025, 1750 rpm (Centrif.)',  
'25 hp SUKUP 25 hp, 1750 rpm (Centrif.)',  
'30 hp CALDWELL CF-22-30 | 3500 rpm (Centrif.)',  
'30 hp DMC CF-30 | 1750 rpm (Centrif.)',  
'30 hp DMC CHS-30 | 3500 rpm (Centrif.)',  
'30 hp GSI CF-30 | 1750 rpm (Centrif.)',  
'30 hp GSI CHS-30 | 3500 rpm (Centrif.)',  
'30 hp KEHO (Centrif.)',  
'30 hp MIDDLE STATE MS 18-300 (Centrif.)',  
'30 hp MIDDLE STATE MS 18-330 (Centrif.)',  
'30 hp NECO 33" (Centrif.)',  
'30 hp SCAFCO 24H2230, 3450 rpm (Centrif.)',  
'30 hp SCAFCO 24L3030, 1750 rpm (Centrif.)',  
'30 hp SHIVVERS 33" Big Blue (Centrif.)',  
'30 hp SHIVVERS 33" Double Inlet (Centrif.)',  
'30 hp SUKUP 30 hp, 1750 rpm, Double Inlet (Centrif.)',  
'30 hp SUKUP 30 hp, 1750 rpm, Single Inlet (Centrif.)',  
'30 hp SUKUP 30-303 (Centrif.)',  
'30 hp SUKUP 3500 rpm (Centrif.)',  
'30 hp SUKUP 44" (Axial)',  
'40 hp CALDWELL CF-22-40 | 3500 rpm (Centrif.)',  
'40 hp CALDWELL CF-33-40 | 1750 rpm (Centrif.)',  
'40 hp DMC CF-40 | 1750 rpm (Centrif.)',  
'40 hp DMC CF-40 | 1750 rpm x 2 inlets (Centrif.)',  
'40 hp DMC CF-50 | 1750 rpm (Centrif.)',  
'40 hp DMC CHS-40 | 3500 rpm (Centrif.)',  
'40 hp GSI CF-40 | 1750 rpm (Centrif.)',  
'40 hp GSI CF-40 | 1750 rpm x 2 inlets (Centrif.)',  
'40 hp GSI CF-50 | 1750 rpm (Centrif.)',

```
'40 hp GSI CHS-40 | 3500 rpm (Centrif.)',  
'40 hp MIDDLE STATE MS 18-300 (Centrif.)',  
'40 hp MIDDLE STATE MS 18-330 (Centrif.)',  
'40 hp NECO 33" (Centrif.)',  
'40 hp SCAFCO 24H2240, 3450 rpm (Centrif.)',  
'40 hp SCAFCO 24L3340, 1750 rpm (Centrif.)',  
'40 hp SHIVVERS 33" Big Blue (Centrif.)',  
'40 hp SUKUP 3500 rpm (Centrif.)',  
'40 hp SUKUP 40 hp, 1750 rpm, Double Inlet (Centrif.)',  
'40 hp SUKUP 40-303 (Centrif.)',  
'50 hp DMC CF-50 | 1750 rpm x 2 inlets (Centrif.)',  
'50 hp DMC CHS-50 | 3500 rpm (Centrif.)',  
'50 hp GSI CF-50 | 1750 rpm x 2 inlets (Centrif.)',  
'50 hp GSI CHS-50 | 3500 rpm (Centrif.)',  
'50 hp MIDDLE STATE MS 18-330 (Centrif.)',  
'50 hp SCAFCO 24H2250, 3450 rpm (Centrif.)',  
'50 hp SCAFCO 24L3350, 1750 rpm (Centrif.)',  
'50 hp SHIVVERS 27" Big Blue (Centrif.)',  
'50 hp SHIVVERS 33" Big Blue (Centrif.)',  
'50 hp SUKUP 3500 rpm (Centrif.)',  
'50 hp SUKUP 50 hp, 1750 rpm, Double Inlet (Centrif.)',  
'50 hp SUKUP 50-303 (Centrif.)',  
'60 hp MIDDLE STATE MS 18-330 (Centrif.)',  
'60 hp SUKUP 3500 rpm (Centrif.)',  
'75 hp SHIVVERS 33" Big Blue (Centrif.)',
```

]

return data



## Models

```
from PyQt5.QtGui import QFont
from PyQt5.QtWidgets import QApplication, QFileDialog

from controller import Compute
from helper import add_roboto_fonts
from views import MainFrame, ResultDialog

from fpdf import FPDF

if __name__ == '__main__':
    ##### instantiating the application, setting font style and application
    name
    app = QApplication([])

    add_roboto_fonts()

    roboto_font = QFont('Roboto')
    roboto_font.setHintingPreference(QFont.HintingPreference.PreferNoHinting)

    app.setApplicationDisplayName('Drying DSS')
    app.setApplicationName('Drying DSS')
    app.setApplicationVersion('1.0')
    app.setFont(roboto_font)

    win = MainFrame()
    win.show()

    ### function to handle the generate button
    def handle_generate():
        dialog = ResultDialog(win)

        crop = win.crops_cb.currentText()
        capacity = win.capacity_le.text()

        tonnes_checked = win.tonnes_radio.isChecked()

        drying_method = win.drying_cb.currentText()
        budget = win.budget_cb.currentText()

        process_compute = False

        capacity_format = 'tonnes'

        if tonnes_checked:
            try:
```

```

if crop == 'Shelled Corn':
    if float(capacity) <= 1702.0 and float(capacity) > 0:
        process_compute = True
elif crop == 'Rough Rice':
    if float(capacity) <= 1385.0 and float(capacity) > 0:
        process_compute = True
else:
    if float(capacity) <= 1846.0 and float(capacity) > 0:
        process_compute = True
except:
    process_compute = False
else:
    if float(capacity) <= 67858:
        capacity_format = 'bushel'
        process_compute = True
    else:
        process_compute = False

if process_compute:
    compute = Compute(crop, capacity, capacity_format, drying_method,
budget)
    results = compute.get_calculated_data()

def handle_save_to_pdf():
    filename, _ = QFileDialog.getSaveFileName(dialog, 'Save File',
'', '*.pdf')

    if filename:
        text = f"""DRYING DSS*
*
*
BIN DIAMETER*
Feet: {results['bin_diameter']['ft']} ft*
Meters: {results['bin_diameter']['m']} m*
*
GRAIN DEPTH*
Feet: {results['grain_depth']['ft']} ft*
Meters: {results['grain_depth']['m']} m*
*
AIRFLOW*
Value: {results['budget']['airflow']} cfm*
*
AIRFLOW RATE*
Value: {results['budget']['airflow_rate']} cfm/ft sq.*
*
HORSE POWER RATING*
Value: {results['horse_power']} hp*
*

```

AVAILABLE FANS IN THE MARKET: -

\*\*\*\*

```
temp = ""*
{}
****
```

```
for item in results['horse_powers']:
    text += temp.format(item)
```

```
text = text.split('*')
pdf = FPDF()
```

```
pdf.add_page()
```

```
i = 0
for x in text:
    if i == 0:
        pdf.set_font('helvetica', size=12)
        pdf.cell(200, 10, txt = x, ln = 1, align = 'C')
    else:
        pdf.set_font('helvetica', size=9)
        pdf.cell(200, 10, txt = x, ln = 1)
    i += 1
```

```
# save the pdf with name .pdf
pdf.output(filename)
```

```
dialog.close()
```

```
dialog.to_pdf_button.clicked.connect(handle_save_to_pdf)
```

```
dialog.bin_diameter_ft.setText(f"Feet:
<b>{results['bin_diameter']['ft']}</b> ft")
dialog.bin_diameter_m.setText(f"Meters:
<b>{results['bin_diameter']['m']}</b> m")
```

```
dialog.grain_depth_ft.setText(f"Feet:
<b>{results['grain_depth']['ft']}</b> ft")
dialog.grain_depth_m.setText(f"Meters:
<b>{results['grain_depth']['m']}</b> m")
```

```
dialog.airflow.setText(f"Value:
<b>{results['budget']['airflow']}</b> cfm")
dialog.airflow_rate.setText(f"Value:
<b>{results['budget']['airflow_rate']}</b> cfm/ft<sup>2</sup>")
```

```
if (results['horse_power'] == '0.00'):
    dialog.horse_power.setText('Not economically viable to dry
grain due to relatively low volume')
else :
    dialog.horse_power.setText(f"Value:
<b>{results['horse_power']}</b> hp")

    dialog.fans_cb.addItem(results['horse_powers'])

    dialog.exec_()
else:
    win.error_label.show()
    win.error_label.setText('Invalid value! Please enter a valid
volume.')
```

win.generate\_btn.clicked.connect(handle\_generate)

```
import sys
sys.exit(app.exec_())
```



## User Interface Design

```

#### UI design
from PyQt5.QtWidgets import (
    QDialog,
    QFrame,
    QRadioButton,
    QVBoxLayout,
    QHBoxLayout,
    QLineEdit,
    QPushButton,
    QLabel,
    QComboBox,
    QScrollArea
)

from PyQt5.QtCore import Qt
from PyQt5.QtGui import QIntValidator

class MainFrame(QFrame):
    def __init__(self, parent=None):
        super().__init__(parent=parent)

        title_label = QLabel('Drying DSS')
        title_label.setStyleSheet('color: #333; font-size: 32px;')
        title_label.setContentsMargins(0, 10, 10, 25)

        ##### Crops
        crops_label = QLabel('Select Grains')

        self.crops_cb = QComboBox()
        self.crops_cb.addItem('Shelled Corn', 'Rough Rice', 'Soybeans')
        self.crops_cb.setMinimumSize(330, 40)
        self.crops_cb.setMaximumSize(330, 40)

        crops_lay = QVBoxLayout()
        crops_lay.addWidget(crops_label)
        crops_lay.addWidget(self.crops_cb)
        crops_lay.setSpacing(5)

        ##### Capacity
        capacity_label = QLabel('Volume')

        self.bushel_radio = QRadioButton('Bushels')

        self.tonnes_radio = QRadioButton('Tonnes')
        self.tonnes_radio.setChecked(True)

```

```

cap_lay = QHBoxLayout()
cap_lay.addWidget(capacity_label)
cap_lay.addStretch(1)
cap_lay.addWidget(self.bushel_radio)
cap_lay.addWidget(self.tonnes_radio)

self.capacity_le = QLineEdit()
self.capacity_le.setPlaceholderText('Capacity')
self.capacity_le.setMinimumSize(330, 40)
self.capacity_le.setMaximumSize(330, 40)
self.capacity_le.textChanged.connect(self.handle_capacity_text_change)

capacity_lay = QVBoxLayout()
capacity_lay.addLayout(cap_lay)
capacity_lay.addWidget(self.capacity_le)
capacity_lay.setSpacing(5)

##### Drying Methods
drying_label = QLabel('Select drying method')

self.drying_cb = QComboBox()
self.drying_cb.addItem('Low Temperature Drying')
self.drying_cb.addItem('Layer Drying',
'Batch-in-bin Drying'))
self.drying_cb.setMinimumSize(330, 40)
self.drying_cb.setMaximumSize(330, 40)

drying_lay = QVBoxLayout()
drying_lay.addWidget(drying_label)
drying_lay.addWidget(self.drying_cb)
drying_lay.setSpacing(5)

##### Budget
budget_label = QLabel('Select budget type')

self.budget_cb = QComboBox()
self.budget_cb.addItem('Low budget')
self.budget_cb.addItem('Medium budget')
self.budget_cb.addItem('High
budget')
self.budget_cb.setMinimumSize(330, 40)
self.budget_cb.setMaximumSize(330, 40)

budget_lay = QVBoxLayout()
budget_lay.addWidget(budget_label)
budget_lay.addWidget(self.budget_cb)
budget_lay.setSpacing(5)

##### First Form Layout
first_lay = QHBoxLayout()

```

```

first_layout.addLayout(crops_layout)
first_layout.addLayout(capacity_layout)
first_layout.setSpacing(30)
first_layout.setAlignment(Qt.AlignmentFlag.AlignLeft)

##### Second Form Layout
sec_layout = QHBoxLayout()
sec_layout.addLayout(drying_layout)
sec_layout.addLayout(budget_layout)
sec_layout.setAlignment(Qt.AlignmentFlag.AlignLeft)
sec_layout.setSpacing(30)

##### Content Frame
content_frame = QFrame()
content_frame.setObjectName('content-frame')

self.generate_btn = QPushButton('GENERATE')
self.generate_btn.setObjectName('gen-btn')

btn_layout = QHBoxLayout()
btn_layout.addWidget(self.generate_btn)
btn_layout.setAlignment(Qt.AlignmentFlag.AlignLeft)

self.error_label = QLabel()
self.error_label.setStyleSheet('font-size: 13px; color: #333;')

content_layout = QVBoxLayout(content_frame)
content_layout.addWidget(title_label)
content_layout.addLayout(first_layout)
content_layout.addLayout(sec_layout)
content_layout.addLayout(btn_layout)
content_layout.addStretch(1)
content_layout.addWidget(self.error_label)
content_layout.setAlignment(Qt.AlignmentFlag.AlignTop)
content_layout.setSpacing(20)

##### Scrolling Area
sa = QScrollArea()
sa.setWidget(content_frame)
sa setFrameShape(QFrame.NoFrame)
sa.setWidgetResizable(True)

##### Main Layout
main_layout = QVBoxLayout(self)
main_layout.addWidget(sa)

self.setMinimumSize(740, 400)
self.setMaximumSize(740, 400)

```

```
self.setStyleSheet(
    """
    MainFrame, QScrollArea, #content-frame {
        background: #fff;
        outline: none;
    }

    QLineEdit {
        outline: none;
        background: #fff;
        border-radius: 5px;
        padding: 5px;
        border: 2px solid #bdbdbd;
    }

    QLineEdit::hover {
        border: 2px solid teal;
    }

    QLineEdit::focus {
        border: 2px solid teal;
    }

    QRadioButton {
        font-size: 14px;
    }

    QComboBox {
        outline: none;
        border: 2px solid #bdbdbd;
        color: #121212;
        selection-background-color: #258cfd;
        border-radius: 5px;
        padding: 5px;
    }

    QComboBox::drop-down {
        subcontrol-origin: padding;
        subcontrol-position: top right;
        width: 20px;
        border-left-width: 0px;
        border-right-width: 0px;
        border-radius: 0px;
        padding-left: 0px;
        margin-left: 0px;
    }

    QComboBox::down-arrow {
```

```

        width: 12px;
        height: 12px;
        image: url(icons/expand_arrow.png);
    }

    QComboBox:on {
        border-color: teal;
    }

    QComboBox QAbstractItemView {
        background: #fff;
        outline: none;
        selection-background-color: teal;
        min-height: 35px;
    }

    #gen-btn {
        outline: none;
        background: teal;
        color: #fff;
        border: none;
        padding: 10px;
        padding-right: 20px;
        padding-left: 20px;
        border-radius: 5px;
    }
    """
)

def handle_capacity_text_change(self, text: str):
    if text:
        self.error_label.hide()

class ResultDialog(QDialog):
    def __init__(self, parent=None):
        super().__init__(parent=parent)

        results_label = QLabel('Results')
        results_label.setAlignment(Qt.AlignmentFlag.AlignCenter)
        results_label.setStyleSheet("font-size: 32px; color: #333;")

        bin_diameter_label = QLabel('Bin Diameter')
        bin_diameter_label.setAlignment(Qt.AlignmentFlag.AlignCenter)
        bin_diameter_label.setStyleSheet("font-size: 24px; color: #333; font-
family: 'Roboto Medium'; font-weight: 500;")

        self.bin_diameter_ft = QLabel()

```

```

self.bin_diameter_m = QLabel()

self.bin_diameter_ft.setAlignment(Qt.AlignmentFlag.AlignCenter)
self.bin_diameter_m.setAlignment(Qt.AlignmentFlag.AlignCenter)

bin_diameter_layout = QVBoxLayout()
bin_diameter_layout.addWidget(bin_diameter_label)
bin_diameter_layout.addWidget(self.bin_diameter_ft)
bin_diameter_layout.addWidget(self.bin_diameter_m)
bin_diameter_layout.setSpacing(5)
bin_diameter_layout.setAlignment(Qt.AlignmentFlag.AlignCenter)
bin_diameter_layout.setContentsMargins(10, 15, 10, 10)

grain_depth_label = QLabel('Grain Depth')
grain_depth_label.setAlignment(Qt.AlignmentFlag.AlignCenter)
grain_depth_label.setStyleSheet("font-size: 24px; color: #333; font-
family: 'Roboto Medium'; font-weight: 500;")

self.grain_depth_ft = QLabel()
self.grain_depth_m = QLabel()

self.grain_depth_ft.setAlignment(Qt.AlignmentFlag.AlignCenter)
self.grain_depth_m.setAlignment(Qt.AlignmentFlag.AlignCenter)

grain_depth_layout = QVBoxLayout()
grain_depth_layout.addWidget(grain_depth_label)
grain_depth_layout.addWidget(self.grain_depth_ft)
grain_depth_layout.addWidget(self.grain_depth_m)
grain_depth_layout.setSpacing(5)
grain_depth_layout.setAlignment(Qt.AlignmentFlag.AlignCenter)
grain_depth_layout.setContentsMargins(10, 15, 10, 10)

airflow_label = QLabel('Airflow')
airflow_label.setStyleSheet("font-size: 24px; color: #333; font-
family: 'Roboto Medium'; font-weight: 500;")
airflow_label.setAlignment(Qt.AlignmentFlag.AlignCenter)

self.airflow = QLabel()
self.airflow.setAlignment(Qt.AlignmentFlag.AlignCenter)

airflow_layout = QVBoxLayout()
airflow_layout.addWidget(airflow_label)
airflow_layout.addWidget(self.airflow)
airflow_layout.setSpacing(5)
airflow_layout.setAlignment(Qt.AlignmentFlag.AlignCenter)
airflow_layout.setContentsMargins(10, 15, 10, 10)

airflow_rate_label = QLabel('Airflow Rate')

```

```
airflow_rate_label.setAlignment(Qt.AlignmentFlag.AlignCenter)
airflow_rate_label.setStyleSheet("font-size: 24px; color: #333; font-
family: 'Roboto Medium'; font-weight: 500;")

self.airflow_rate = QLabel()
self.airflow_rate.setAlignment(Qt.AlignmentFlag.AlignCenter)

airflow_rate_lay = QVBoxLayout()
airflow_rate_lay.addWidget(airflow_rate_label)
airflow_rate_lay.addWidget(self.airflow_rate)
airflow_rate_lay.setSpacing(5)
airflow_rate_lay.setAlignment(Qt.AlignmentFlag.AlignCenter)
airflow_rate_lay.setContentsMargins(10, 15, 10, 10)

horse_power_label = QLabel('Horse Power Rating')
horse_power_label.setAlignment(Qt.AlignmentFlag.AlignCenter)
horse_power_label.setStyleSheet("font-size: 24px; color: #333; font-
family: 'Roboto Medium'; font-weight: 500;")

self.horse_power = QLabel()
self.horse_power.setAlignment(Qt.AlignmentFlag.AlignCenter)

fans_label = QLabel('<b>Available fans in the market</b>')
fans_label.setAlignment(Qt.AlignmentFlag.AlignCenter)

self.fans_cb = QComboBox()
self.fans_cb.setMinimumSize(400, 35)
self.fans_cb.setMaximumSize(400, 35)
self.fans_cb.setMaxVisibleItems(20)

fans_lay = QVBoxLayout()
fans_lay.addWidget(fans_label)
fans_lay.addWidget(self.fans_cb)
fans_lay.setSpacing(5)
fans_lay.setContentsMargins(10, 15, 10, 10)
fans_lay.setAlignment(Qt.AlignmentFlag.AlignCenter)

horse_power_lay = QVBoxLayout()
horse_power_lay.addWidget(horse_power_label)
horse_power_lay.addWidget(self.horse_power)
horse_power_lay.addLayout(fans_lay)
horse_power_lay.setSpacing(5)
horse_power_lay.setAlignment(Qt.AlignmentFlag.AlignCenter)
horse_power_lay.setContentsMargins(10, 15, 10, 10)

self.to_pdf_button = QPushButton('SAVE TO PDF')
self.to_pdf_button.setMinimumHeight(35)
self.to_pdf_button.setObjectName('btn')
```

```
btn_layout = QHBoxLayout()
btn_layout.addWidget(self.to_pdf_button)
btn_layout.setAlignment(Qt.AlignmentFlag.AlignCenter)
btn_layout.setContentsMargins(10, 15, 10, 10)

results_layout = QVBoxLayout(self)
results_layout.addWidget(results_label)
results_layout.addLayout(bin_diameter_layout)
results_layout.addLayout(grain_depth_layout)
results_layout.addLayout(airflow_layout)
results_layout.addLayout(airflow_rate_layout)
results_layout.addLayout(horse_power_layout)
results_layout.addStretch(1)
results_layout.addWidget(self.to_pdf_button)
results_layout.setAlignment(Qt.AlignmentFlag.AlignTop)
results_layout.setContentsMargins(10, 10, 10, 10)

self.setMinimumSize(400, 720)
self.setStyleSheet("""
    ResultDialog {
        background: #fff;
    }

    #btn {
        outline: none;
        background: teal;
        color: #fff;
        border: none;
        padding: 10px;
        padding-right: 20px;
        padding-left: 20px;
        border-radius: 5px;
    }
""")
```



Drying DSS

## Drying DSS

Select Grains

Volume   Bushels  Tonnes

Select drying method

Select budget type

**GENERATE**

*Figure 3 - Inputs for Simulation 1*



Drying DSS

? X

## Results

### Bin Diameter

Feet: **21.00** ft

Meters: **6.40** m

### Grain Depth

Feet: **14.50** ft

Meters: **4.42** m

### Airflow

Value: **3986.80** cfm

### Airflow Rate

Value: **11.60** cfm/ft<sup>2</sup>

### Horse Power Rating

Value: **0.31** hp

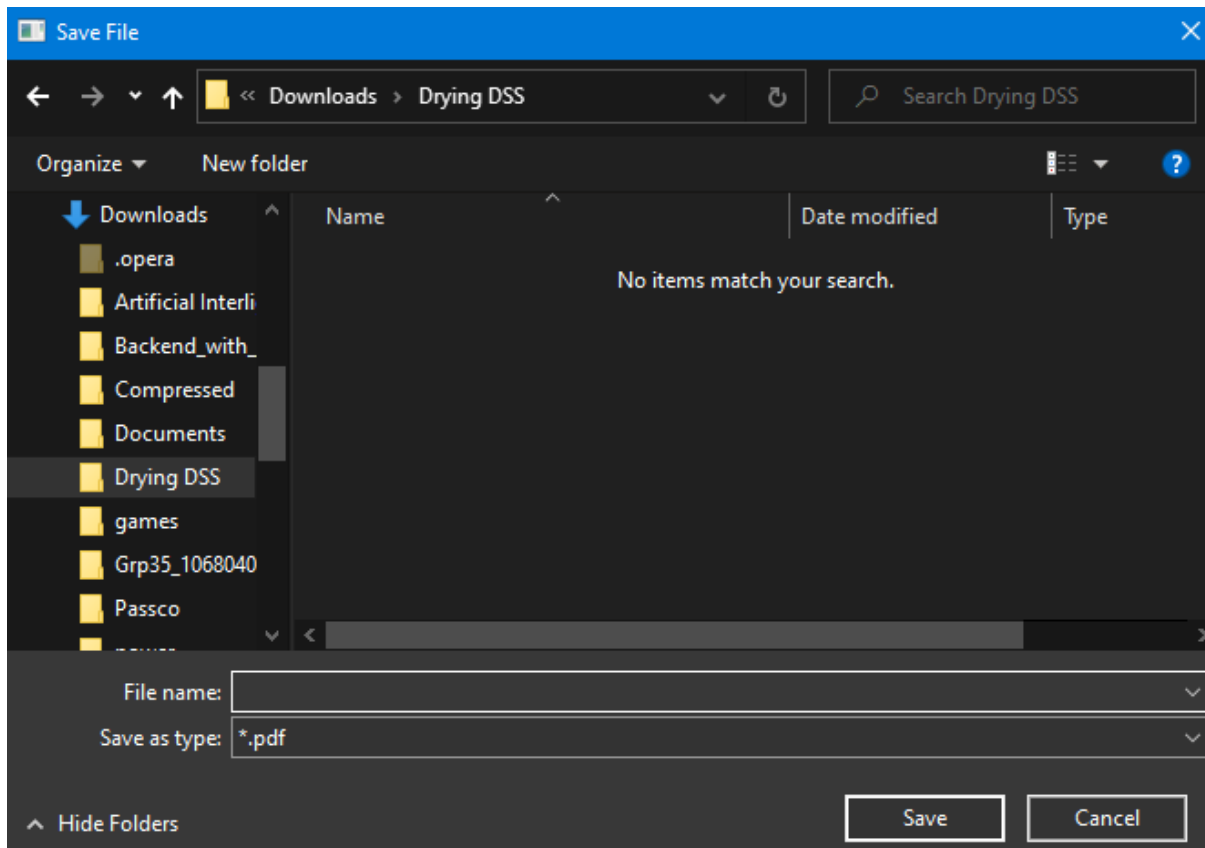
### Available fans in the market

0.33 hp AEROVENT 1240-DW | 12" (Axial) ▾

SAVE TO PDF

*Figure 4 - Outputs for Simulation 1*

INTEGRI PROCEDAMUS



*Figure 5 - PDF exportation of results*

