OPEN ACCESS

Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) | ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Design and Performance Evaluation of an Air Flow Meter for Drying Cassava Chips

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DOI: 10.36348/sjet.2024.v09i02.003 | **Received:** 18.12.2023 | **Accepted:** 23.01.2024 | **Published:** 02.02.2024

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Abstract

Drying is an important unit operation in the processing of fresh cassava tubers into cassava chips. An air flow meter is a device that measure airflow. Airflow meter and direction sensing are importance in many fields, including the monitoring on vehicle engine performance. The airflow meter for cassava chips measures how much air is flowing through the cassava chips. There are many reasons and ways to measure airflow, this technical method of explores the use of air flow meter to measure cassava chips in order to ensure the proper airflow to dry the cassava chip, which will improve the value chain of cassava processing. This research work focused on the design and performance evaluation of an airflow meter for drying cassava chips. The air flow meter was made from locally available materials and it consists of a blower, pressure, sensor, temperature sensor, heating chamber which was used to carry out several tests on cassava chips. From the test conducted during drying operation, at a temperature of 90^0c for a 372g of cassava chips, it takes a period of 180 minutes (3hours) with an airflow of $133m^3$/sec to dry it to a safe moisture content. At temperature 110^0c for 617g of cassava chips, it takes a period of 240 minutes (4hours) with an airflow of $209m^3$/sec to dry it to safe moisture content. The efficiencies of the drying mechanism and measuring airflow device are 70% and 65% respectively. The sample dried with airflow meter still retain their white colours, thus indicating no mould growth.

Keywords: Air Flow Meter, Cassava Chips, Drying, Post-Harvest, Moisture Content, Agricultural Produce.

I. INTRODUCTION

Nigeria is a developing country with a strong belief and expectation that agriculture will play a significant role in quickly bringing about the nation's much-needed development. Automation of agro-technology entails the application of cutting-edge technologies to develop the crops that are being produced, minimize the need for human labor, and boost farmer revenue [1]. Nigeria is among the world leaders in cassava production [1-3]. For use in food applications, livestock feeds, and the production of ethanol, dried cassava (Manihot esculenta Crantz) roots are most frequently sold as pieces in exporting nations like Nigeria, Ghana, the Philippines, the United Republic of Tanzania, and some regions of Asia. The dried bits—often referred to as "chips"—are amorphous slices or pieces of roots that are typically no longer than 5 cm in length for convenience in silos. Due to the significance of this product, standards and specifications on the quality and compositional criteria have been set for dried cassava chips, and the maximum moisture level is stated as 13–14% wet [4, 5]. The goal of these initiatives is to increase the export of the crop and its by-products. The unprocessed cassava tuber has poor storage properties; thus, in order to reduce degradation and losses during travel, the product must be processed into a form that is more easily kept. One type of cassava that may be conveniently stored and transported without deterioration or loss is chips [6]. Due to the significance of this product, standards and specifications for quality and compositional criteria have been set for dried cassava chips, and the maximum moisture level is stated as 13–14% wet basis [4-7]. Several researchers have undertaken numerous investigations into the creation of dried cassava chips of a particular size. According to the [5–12], study, various sizes, geometries, drying conditions, and drying equipment have all been successfully studied. Numerous studies have discussed various elements of the roots' drying behavior, including moisture, drying rate, and moisture ratio curves [7-13], the calculation of diffusion coefficients [11, 12], and the derivation of drying rate constants [12, 13]. Several researchers used one to seven thin layer models for modeling or curve fitting [7-13].

Itifamus and Mbajiorgu (2014) developed a portable air flow digital meter for grain drying. Their findings suggest that the nearer the meter to the source of drying air, the higher the impact of the stream of air flow on the meter. An air flow meter is a device that measures the rate, pressure, and direction of airflow in a duct or pipe. Apart from using an air flow meter to dry cassava chips, they can be used for other purposes, such as monitoring ventilation, optimizing combustion, controlling emissions, and ensuring safety. The rate of airflow is also known as the velocity or volume of air. Air flow meters can also measure the pressure and direction of airflow, which are important parameters for some applications. Air flow meters sense the movement of air and convert it into an electrical signal. The signal is then displayed, recorded, or transmitted to a controller or computer for further processing and analysis (electrica4u.com). An airflow meter measures the amount of air passing through the cassava chips. It measures the mass of air flowing through the device per unit of time, not the volume of air moving through the cassava chip. Thus air flow meters are simply an application of mass flow meters for a special medium. Typically, mass air flow measurements are expressed in the units of kilograms per second (kg/s). In engineering, the amount of air that flows through a specific piece of equipment in a unit of time is measured as airflow.

Air can be quantified by its mass or by its volume. It must typically be measured in terms of mass. Since air is a gas, its volume is affected by temperature. The device that controls airflow is referred to as a damper. The airflow can be modified by the damper, either to enhance, lessen, or entirely stop it. An air handler is a more complicated device that has the ability to both regulate and create airflow. Numerous applications require the measurement of airflow, including ventilation (to ascertain how much air is being replaced) and engines (to regulate the air-fuel ratio). When air is forced through a bulk crop, it must travel through narrow paths between individual particles [16, 17]. For packaged crops, air must travel through or between individual containers. Friction along air paths creates resistance to airflow. Fans (blowers) must circulate enough pressure to overcome this resistance and move air through the crop. The Agricultural Engineer is constantly exploring ways of obtaining data handling and processing, and the instruments available are often crude and prone to errors owning to their analogue format. More modern digital instruments are therefore, required and desirable.

Statement of the Problem

In order to improve the value chain of harvested cassava tubers which is a very important food crop. There is therefore the need to process cassava into other useful forms particularly cassava chips for adequate food supply. An airflow meter is designed and developed to aid in the production of cassava chips by determining the velocity of air that is capable of drying cassava per unit time. It measures how much air is flowing through the cassava chips. The objectives of this research are to design and develop air-flow digital meter for cassava chips as well as to evaluate the performance of the developed airflow meter. The objective of this research is to improve cassava chip drying process by development of an air flow meter and subsequent performance assessment of the air flow meter.

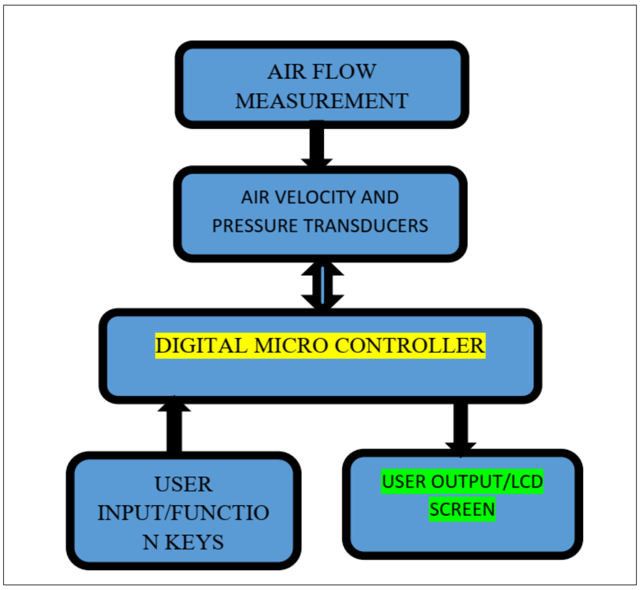

Figure 1: Flow chart of air flow meter for cassava chips

II. MATERIAL AND METHODOLOGY

2.1. Material Selection

An airflow meter was constructed with the following components, heater, blower, pressure sensor, temperature sensor, chamber, and chimney. The airflow meter uses electricity as its source of energy with a power of 3000watt, while the airflow varies with the material. It consist s of a blower, pressure sensor, temperature sensor, heating chamber.

2.2. Experimental Procedure

Freshly harvested cassava roots were gotten from Second Gate Farm, peeled manually and washed with clean water. The root was then steeped for 3 days. Drying operation was done by heater in the airflow meter.

2.3. Components of an Air Flow Meter

2.3.1. Hopper

This is the part of the machine; it serves as the collecting units where cassava chips are fed into the machine .it will be made of galvanized sheet.it is in form of tray

2.3.2. Centrifugal Blower

A suction air steam is supplied by a centrifugal blower operated directly, blower produces air and it circulates through the chamber of the machine.

2.3.3. Electric Heater

This is a device for generating heat and is a process in which electrical energy is converted to heat. This device uses Nichrome wire as the active element.

2.3.4. Electronic Speed Control Sensor

Electronic Speed Control or ESC is an Electric circuit with the purpose to vary on the speed of the blower. ESCs are often used on electrically powered radio controlled models, with the variety most often used for brushless motors essentially providing an electronically genetard three-phase electric power low voltage source of energy for the motor

2.3.5. Thermostat

Thermostat is a component which sense the temperature of a system so that the system's temperature is maintained near a desired set point. The thermostat can often be main control unit for heating or cooling system

2.3.6. Heater

This is a device for supply heating. The heater used for this project is rated 3000watt, the drying temperature can be raised to 60-1100c without gelatinization setting in.

2.3.7 Sensor

A sensor is a device that detect and responds to some types of input from the machine. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of the environmental phenomena.

There are different types of sensors which are temperature sensor, pressure sensors, ultrasonic sensor, etc.

Figure 2: Sensor

2.3.8. LCD Display

This is the part of the machine in which all the air passing through the machine is shown and it will display in digital form, there are different kind of display board which are digital and analog, but digital is easy to read than analog.

Figure 3: LCD display

2.3.9. Resistance

Resistance is a passive two-terminal electrical component that implements electrical resistance as a circuit element. In electronic circuits. Resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses.

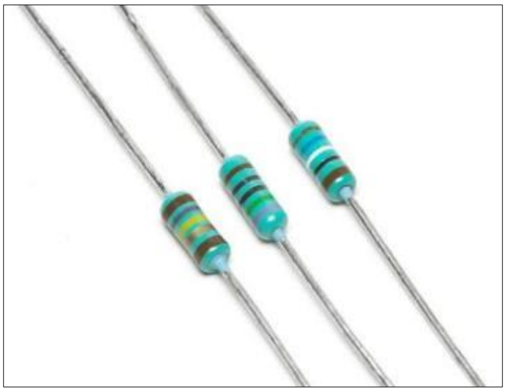

Figure 4: Resistor

2.3.10. Capacitor

Resistance is a passive two-terminal electrical component that stores electrical energy in an electric field. The effects of a capacitor is known as capacitance. While capacitance exists between any two electrical conductors of a circuit in sufficiently close proximity, a capacitor is specifically designed to provide and enhance this effect for a variety of practical applicatios by consideration of sizes, shape, and positioning of closely spaced conductors and the intervening dielectric material.

Figure 5: Capacitor

2.3.11. Diode

Diode is a two-terminal electronic component that conducts primarily in one direction (asymmetric conductance); it has low (ideally zero) resistance to the current in one direction, and high (ideally infinite) resistance in the other.

Figure 6: Diode

Amount of Moisture to be removed

The formula to calculate the total amount of moisture to be removed (Mw) is given by Bassey and Schmidt (1987) as:

2.4. Theory of Air Flow Rate Essential in Estimating Fan Power Requirements

Fans, especially axial fans are very essential in continuous flow drying whereby they influence the speed and uniformity of drying. According to Onwualu *et al.*, (2006) the efficiency of an axial fan can be estimated using

$N=P_{in}/P_{out}$ …………………………………………….(i)
where;
N=efficiency (%)
P_{in} =input power (watts);
P_{out} =output power (watts)
The flow rate of drying air is also essential in determining the power output required in the equation state above. So
Vσh; …………………………………………(ii)
where,V= air flow rate m^3/s H= pressure head, m of water
σ= density of air kg/m^3

Wickle and Morey (2002) in their work concluded that fans are usually described by the horsepower (hp) rating of the motor used to drive the impeller. It's helpful when selecting fans to estimate the power requirement first so you know where to start looking in the manufacturer's catalog

According to Hunt (1977), the power required by such fans discussed here is given by
P=Vh/ce………………………………………….(iii)
Where P= power required, Kw (HP)
V=air flow, m3/mm (ft^3/min)
H= static pressure head, mm (in.) of water
E=static efficiency, decimal
C=constant, 6000(6350)

2.5. Mode of Operation

When the system is turned on to a specific temperature range and the electric speed control is also set to a specific flow rate using the first sensor. As the system runs the second airflow sensor will begins to take the airflow reading of the air passing through the cassava chips being dried. The total airflow through the cassava chip will be the subtraction of the initial airflow from the final airflow. The LED Digital display tells us the airflow before the air hits the product and the air flow rate after hitting the product. The rate of air that dries the cassava chips is determine by subtracting the initial airflow from the final airflow in the system.

III. RESULT AND DISCUSSION

The airflow meter was completely designed and constructed, different tests were carried out in order to evaluate the performance of the machine
The airflow of the cassava were determined at different temperature during the testing period.

3.1. Temperature Ranges

When drying at 90^0c for 372g of cassava root, it takes a period of time of 180 minutes (3hours) with an airflow of 133m^3/sec. At 65^0c of temperature for 450g of cassava root, it lasted for 270 minutes (4.5hours) with an airflow of 238m^3/sec. At 100^0c for 617g of cassava root, it lasted for 1380 minutes (23hours) with an airflow of 209m^3/sec.

3.2. Experiment 1

Table 1: A table showing the temperature ranges and cassava chips drying rate at 90^0c

S/N	MOISTURE (%)	THICKNESS(cm)	AIRFLOW (m^3/sec)	TIME
1	14	4	56	15
2	11	11.2	41	15
3	12	4.5	39	15
4	13.5	2.3	33	15
5	12.5	7	20	15
6	11.2	6.2	29	15
7	10.7	8	28	15
8	11.3	5.1	14	15
9	12.5	6.4	22	15
10	13.2	9	18	15

Table 2: A table showing the temperature ranges and cassava chips drying rate At 180^0c

S/N	MOISTURE (%)	THICKNESS(cm)	AIRFLOW (m^3/sec)	TIME
1	11	4	56	30
2	12.3	11.2	41	30
3	12	4.5	39	30
4	11.1	2.3	33	30
5	14	7	20	30
6	12.3	6.2	29	30
7	13	8	28	30
8	12.6	5.1	14	30

Plate 1: image of an digital airflow meter machine

Plate 2: An Airflow meter with opening tray

Plate 3: Steep cassava chip

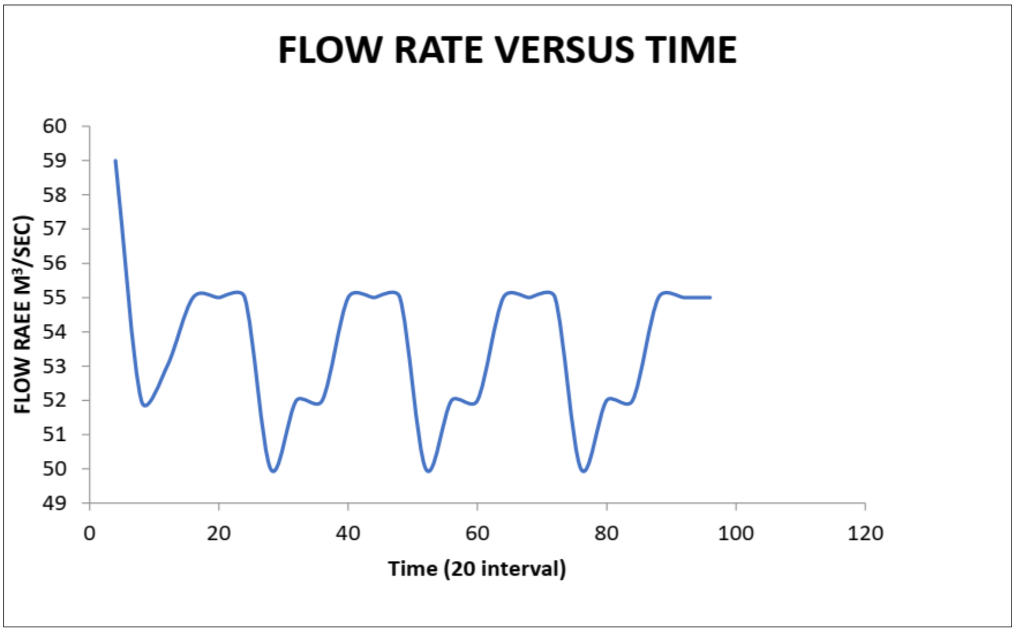

Figure 7: A curve showing air flow rate

4.0. CONCLUSION

The velocity of the air movement and absolute pressure exerted by the airflow within the open space and inside the cassava chips and between the mesh and cassava chips surface interface denote an importance advancement in local technology. This indeed has a correlation with the outputs of developed technologies in the developed economics. For each mass flow case, the velocity magnitude and the absolute pressure exerted by the airflow increased near each of the air inlets. Hence, the findings suggest that the nearer the meter to the meter to the source of drying air, the higher the impaction of the stream of airflow on the meter. This also implies that in a deep-bed drying system, the layers closer to the air blowers are likely to dry faster than those at the middle and the extreme end. This adequately agrees with the views of (Chakraverty, 1988 CIGR, 1999 and Ojha and Michael, 2006).

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