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Development of a Portable Machine for Drying Vegetable Leaves for Preservation

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Abstract

Vegetables are edible products of a plant and it leaves (edible and inedible) serve as vegetable nutrients when eaten raw or cooked (as the case may be). The importance of vegetables and their leaves cannot be over-emphasized, as they are rich in vitamins and minerals but low in calories thus, resistance to heart attack and high blood pressure. But because they (vegetable leaves) are prone to rot, they need to be well preserved in order to minimize pathogenic bacteria and kept at their best quality to avoid excess wastage when they are out of season. Here comes in the idea/ thought of developing a portable machine to preserve them through the process of drying. The machine was designed to be portable, containing two equal rectangular shaped cabinets, each having three equal squared tray plates. This study develops a portable machine for drying vegetable leaves for preservation; to work electrically, using a circuit box containing a switch, a contactor and a temperature controller. The source of heat was through a heating filament of capacity 1,800 . The developed machine also contained a 12 , 25 D.C motor and a propeller shaft which works to extract moisture from the drying materials being: fluted pumpkin leaf (Telfaria accidentalis), water leaf (Talinum triangulare) and bitter leaf (Vernonia amygdalina). The result of this study shows the mass of water removed during drying for the aforementioned three varieties of vegetable leaves as 3,500 , 4,387.5 and 3,850 respectively; amount of moisture extracted as: 72.9%, 75%, 73.3% in that order; total heat energy required to extract moisture as: 2,858.4 and the efficiency of the developed machine was evaluated to be 70.6%. This implies that the developed machine is capable of drying the three varieties of vegetable leaves used for this study thereby avoiding wastage, high price when out of season among other benefits.

Keywords: *Portability, Drying, Vegetables Leaves and Preservation*

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Background to the Study

A portable machine is a machine designed to be easily and safely moved or carried from place to place with less or no external means of transportation. This is in line with the simple definition of portable devices by Margaret Rouse (2013) as devices that can easily be carried which she also named handheld or mobile devices. A typical application and advantage of portability in engineering is the use of portable hand-drill in creating holes in wooden doors instead of transporting the drilling machine from the site to the final place of installation or taking a number of wooden doors to the site and then transporting them back to their final place of installation after appropriate machining operations have been carried on them.

Another application of portable machines is in the repair work on large parts and considerably complex systems such as: aircrafts, ships, power stations, metal fabrication and heavy machinery (Krishna Dave *et al.* 2014). No doubt, the essence of portability in engineering design cannot be overemphasized, as it includes but not limited to the following: simplicity of mechanical works such as: cutting, drilling, sawing e.t.c, easy mobility from place to place, just to mention a few. Every portable machine is designed for a/ some specific objective(s). The aim of this study is thus, centered on developing one for drying vegetable leaves.

The development of this machine for drying vegetable leaves will be clearly distinguished from oven drying, as there will be no room for 'Case hardening' which would have occurred in oven drying if not tested for maintenance of relatively low temperature though being a precautionary measure thus, in this development, there will be proper drying in the interiors. The problem behind this study is such that in the production of engineering items, a significant challenge (considering: time, cost, flexibility, energy constrain among other logistical factors) is the difficulty in transporting such items from the site of their production to their final place of installation where various machining operations are required, hence, the need for portability. Meanwhile, a major problem in the food processing industry is the damage, decay or spoilage of raw food items when not used over a period of time bearing in mind that pumpkin leaves among other vegetable leaves are seasonal and highly perishable. Hence, the aim of this study is to develop a portable machine for drying vegetable leaves for preservation. This will be achieved through designing, fabricating and carrying out a performance evaluation, as stated objectives. The study is thus, to provide a means of preserving vegetable leaves so as to avoid decay, damage or spoilage and general wastage thereby saving cost in this hard-economic situation of Nigeria among other countries world-wide. This study is limited to the preservation of only vegetable leaves, using fluted pumpkin leaf, water leaf and bitter leaf as the selected vegetable variety.

Literature Review

Drying as a means of preservation involves the application of heat in dehydrating a product. It (drying) reduces water activity and avoids microbial growth and deteriorative chemical reactions (Rahman and Perera, 2007). This, however, is based on the principle of excess moisture removal from foods being the major advantage of the drying method and thus, prevents bacteria from growing in it and food spoilage by micro-organisms.

Asaad's article (2006) described three common methods used in drying leafy vegetables:
(i) Sun Drying
(ii) Solar Drying and
(iii) Oven Drying.
He considered the solar dryer the best among them.

Dr. Naseer *et al.* (2013) in their article on different drying methods, their applications and recent advances identified various drying techniques: sun drying, solar drying, freeze drying and oven drying. This research work is aimed at developing a portable machine that can dry vegetable leaves for preservation.

According to the technical centre for agriculture and rural development in the United Nations, drying fresh vegetables and fruits reduces bulkiness and weight and so eases storage and transportation, and avoids wastage. They further identified two major means of drying vegetable leaves: using cool pot and sun drying. According to a led author: Julie Gardie Robinson (2007), drying was rated excellent as a method of preservation of vegetables like carrots, sweet corn, garlic e.t.c by the University of Georgia. From the result of an experiment carried out by Raji *et al.* (2016), after all step by step process of drying; starting from first principle down to slicing the fluted pumpkin leaves with a sharp knife, the maximum desired moisture content was 84.00%.

In a similar experiment conducted by Ayo J.A *et al.* (2011), the moisture content of water leaf (Talinum triangulare) was found to be 49.34%.
Again, in research carried out by Fred Oboh *et al.* (2009) the maximum desired moisture content found in bitter leaf was 77.43%.
I therefore hope to compare and contrast my results with these aforementioned literatures at the end of this study.

Materials and Methods/Methodology/Experimental Procedure Materials and Methods
The materials used for this development include the following:
1. Mild Steel Plate (for the inner and outer body of the machine, the door plate, the base/ seat of the machine, the circuit box and the propeller.
2. Mild Steel Pipe (for the body frame, door frame and base frame of the machine)
3. Mild Steel Angle Iron (for the inner tray seat and the legs of the machine)
4. Mild Steel Flat Bar (for the door handle and locker
5. Stainless Steel plate (for the tray plates)
6. Galvanized plate (for the top of the support structure)
7. Fiber Glass (for the insulation)

Design Theories
Cabinet Design
The developed machine consists of the following design specifications: Number of cabinets – 2
Number of trays for each cabinet – 3

The area and volume of the cabinets and the trays were determined using the equations below:
$l \times b$and $\quad l \times b \times h$ respectively.
$A_C = 0.375m \times 0.3m$
Area of each cabinet = $0.1125m^2$

But total area of the cabinets of the machine = $0.1125 \times 2 = 0.225m^2$
On the other hand, volume of the cabinet $V_C = l \times b \times h$
$V_C = A_C \times h$
$O.225 \times 0.35$
$V_C = 0.07875m^3$

But total volume of the drying machine =drying capacity = $2 \times V_C 2 \times 0.0787 = 0.158m^3$
Determination of Area and Volume of Trays

The six (6) square shaped trays were of equal dimensions as shown below:
$l = b = 30.4cm \text{ and } h = 1.9cm$
$Area = 0.0924m^2$and $Volume = 0.0018m^3$

Frame Design
The frame of the vegetable leaf drying machine provides structural support and stability to the entire machine. The material used for the frame was of high resistance to withstand the smoke/ vapour during drying.

Results and Discussions
The rate of temperature change for each drying material was determined using various temperature differences and 7their respective time. The maximum drying temperature set on the temperature controller was 75^0 . This was recorded as presented on the table below:

Table 1: Fluted Pumpkin Leaf *(at initial temperature* 31^0C*)*

S/N	Temperature Readings (^0C)	$\Delta(^0C)$	$Time\ (s)$	$\frac{\Delta\theta}{t}$ ($^0C/s$)
1. 31	0	0	0	
2. 38	7	300	0.023	
3. 41	3	60	0.05	
4. 51	10	315	0.032	
5. 61	10	615	0.016	
6. 71	10	735	0.014	
7. 75	4	225	0.018	

Since change in temperature is certainly not constant, the average rate of temperature change was determined.

Average rate of temperature change = 0.022^0C

Table 2: Water Leaf *(at initial temperature* 45^0C*)*

S/N	Temperature Readings (^0C)	$\Delta\theta(^0C)$	*Time* (s)	$\frac{\Delta\theta}{t}$ ($^0C/s$)
1.	45	0	0	0
2.	50	5	90	0.056
3.	55	5	200	0.025
4.	60	5	330	0.015
5.	65	5	600	0.008
6.	70	5	920	0.005
7.	75	5	1,500	0.003

Average rate of temperature change = 0.016^0C

The developed machine was used to conduct a test in order to determine the amount of moisture removed from each variety of vegetable leaves. The result is recorded as represented in the table below:

Table 3: Amount of Moisture content (%) removed

Vegetable Leaves	m_b (g)	m_1(g) $m_b - m_0$	$m_a(g)$	$m_2(g)$ $m_a - m_0$	$m_w(g)$ $m_1 - m_2$
Pumpkin Leaf	5,100	4,800	1,600	1,300	3,500
Water Leaf	6,150	5,850	1,762.5	1,462.5	4,387.5
Bitter Leaf	5,550	5,250	1,650	1,400	3,850

Where $m_0 = 300g\ or\ 0.3kg$

Now applying equation (3.4) above:

$$A_m\ (Pumpkin\ Leaf) = \frac{3{,}500}{4800} \times 100$$

$$A_m\ (Pumpkin\ Leaf) = 72.9\%$$

$$A_m\ (Water\ Leaf) = \frac{4{,}387.5}{5{,}850} \times 100$$

Parts/ Parameters	Input Data	Calculation	Result
Area of Cabinet (m^2)	$l = 0.375m$ $w = 0.3m$	Area is $l \times b$	the area of the cabinet is $0.225m^2$
Volume of $w = 0.0035m$	$lh = 0.35cm$	Volume is $l \times b \times h$	the volume of Cabinet (m^3) the cabinet is $0.158m^3$
Area of Tray (m^2)	$l = w = 30.4cm$ $= 0.304m$	Area is l^2	the area of each tray is $0.0924m^2$
Volume of Tray (m^3)	$Area = 0.0924m^2$ $h = 1.9cm$ $0.019m$	Volume is $A \times h$	the volume of each tray is $0.0018m^3$
Area of the $= 0.83m$	$l_f = 83cm$ $b_f = 37cm = 0.37m$	$l \times b$	the area of the Frame frame (m^2) is $0.307m^2$

Volume of $= 0.9m$	$h_f = 90cm$	$A \times h$	the volume of the frame the frame is $0.28m^3$
Mass of the l Driving Shaft (kg)	$\rho = 7{,}850kgm^{-3}$ $\pi = \frac{22}{7}$ $d_s = 6mm = 0.006m$ $l = 60mm = 0.06m$	$\rho \frac{\pi d_s^2}{4}$	the mass of the shaft is $0.013kg$
Rate of Temperature Change Δ^0C/s Pumpkin Leaf	$\Delta\theta = 44^0C$	$\frac{\Delta\theta}{t}$	the rate of temperature change is: 0.022^0C
Water Leaf	$\Delta\theta = 30^0C$		0.016^0C
Speed of Rotation of the Shaft (m/s)	$d = 6mm$ $r.p.m = 2{,}500$	$\frac{diameter\ (mm)}{19{,}108} \times r.p.m$	the speed of rotation is $0.785m/s$
Amount of Moisture Removed from water (%)		$\frac{m1-m2}{m1} \times 100$	
Fluted Pumpkin leaf	$m_1 = 4.8kg$ $m_2 = 1.3kg$	$m_1 - m_2$	the mass of water removed is $3.5kg$ the amount of moisture removed is 72.9%
Water leaf	$m_1 = 5.85kg$ $m_2 = 1.46kg$	$m_1 - m_2$ $\frac{m1-m2}{m1} \times 100\%$	the mass of water removed is $4.39kg$ the amount of moisture removed is 75%
Bitter leaf	$m_1 = 5.25kg$ $m_2 = 1.4kg$	$m_1 - m_2$ $\frac{m1-m2}{m1} \times 100\%$	the mass of water removed is $3.85kg$ the amount of moisture removed is 73.3%
Heat Energy to Dry the leaf	$m = 4.8\ kg$ $c_p = 5{,}174JkgK^{-1}$ $\Delta\theta = 44^0C$	$mc_p\Delta\theta$	the heat energy needed is $1{,}092.7kJ$
Heat Energy to Remove Moisturer (J) Fluted Pumpkin leaf	$m = 0.53kg$ $L = 504.49J/kg$	$m_w \times (h_g - h_f)$	$1{,}765.7kJ$
Total Heat Needed		$Q_1 + Q_2$	$2{,}858.4kJ$
Efficiency W_{output}	$= 2{,}858.4kJ$	$\frac{Work\ output}{work\ input} \times 100\%$	the efficiency of the

The findings from table 3 reveal that there was a significant loss in mass in the three varieties of leaves used for this study. However, this difference varies from material to material based on the level of water content present in them. Also, the moisture content varied for each leaf, as that of water leaf was found to have the highest moisture content being 75%. This is a clear significance that when any fresh vegetable leaf is purchased, it still contains a certain amount of water/ moisture content. Also, the heat/ thermal energy needed to remove the moisture were in two phases: that needed to dry up the leaf and that needed to evaporate the moisture content from the leaf. This requires a high magnitude of thermal energy in total.

Conclusion

The study has been able to design, fabricate and develop a portable machine for drying vegetable leaves for preservation. In conclusion, this study has: designed, fabricated a portable machine used for drying vegetable leaves using two different varieties of vegetable leaves (Fluted Pumpkin leaf and Water leaf) and the working performance of the machine have been evaluated based on its efficiency as 70.6%. This study has not just reminded the world of the existing methods of preservation, but has also developed a machine for this very purpose.

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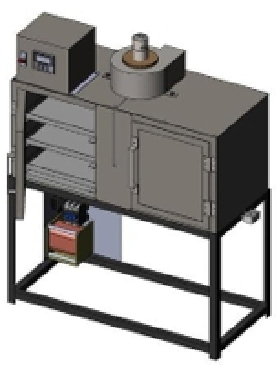
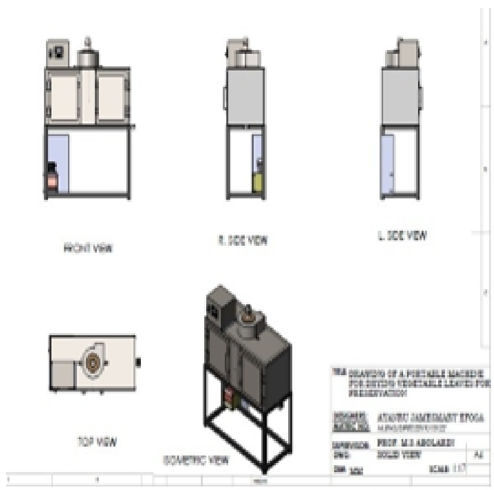
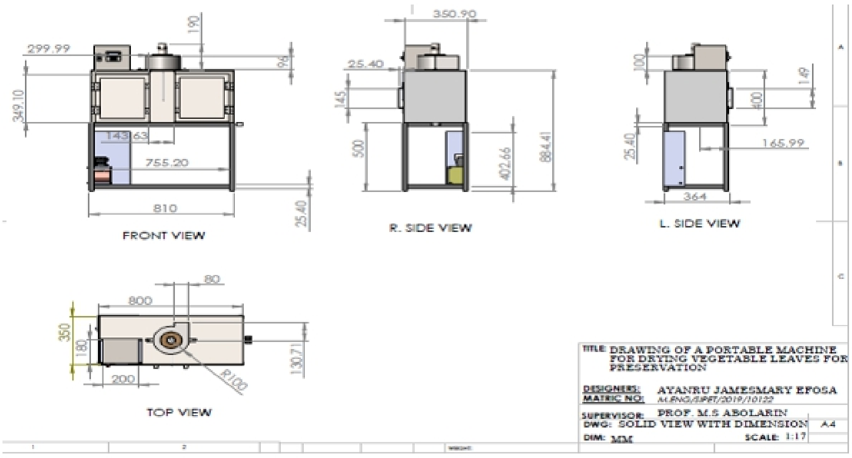
Appendices



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L. SIDE VIEW
TOP VIEW
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25.40
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130.71
TITLE: DRAWING OF A PORTABLE MACHINE FOR DRYING VEGETABLE LEAVES FOR PRESERVATION
DESIGNERS: AYANRU JAMESMARY EFOSA
MATRIC NO: M.ENG/SIPET/2019/10122
SUPERVISOR: PROF. M.S ABOLARIN
DWG: SOLID VIEW WITH DIMENSION
A4
DIM: MM
SCALE: 1:17