Development and Performance Evaluation of a Rain Shade for a low scale Agricultural Produce

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ABSTRACT: This paper reports on the development and performance evaluation of a rain shade for a low scale agricultural produce, The rain shade consists of a geared D. C motor, 12V battery, sensor, a roller tube in which a polyester fabric is wound, two extension arms attached directly to the roller tube that pulls out the fabric when the device is open to protect a designated area from rain and pulls it back when the rain stops and a stand. On   performance evaluation of the rain shade, it was to able protect maize cobs by opening in average periods of 0.5,1,1 and 1 second and retracting in average periods of 150, 411,470 and 480 seconds respectively. © JASEM

INTRODUCTION

In many agricultural countries, large quantities of food products are dried to improve shelf life, reduce packaging cost, lower weights, enhance appearance, retain original flavor and maintain nutritional value (Saeed *et al*, 2008). The examples of the products that are dried include cereals,oilseeds legumes and some processed food(Jayas and Singh,2014).The major objective of drying food products is the reduction of moisture content to a level which allows safe storage over an extended period (Sahari and Driscoll,2013). Sun drying of agricultural produce is the earliest and traditional method of reducing their moisture content . Although with appropriate harnessing technology, solar dryer evolved,sun drying is widely used in developing countries and most especially in the rural areas. This method involves spreading the agricultural produce in a tray or the ground or raised platform which is aerated and exposed to sunlight. Alamu *et al*(2014) opined that since the agricultural produce are laid in the open sky, there is greater risk of spoilage due to adverse climatic conditions like rain, moist among others.

Sun drying of agricultural produce is efficient and less labour intensive during dry season but during raining season, it is tasky in the sense that the agricultural produce has to be watched over and evacuated when there is rain Adebayo(2014). So in order to reduce this burden, the   development of a rain shade was embarked on in this research work.

MATERIALS AND METHOD

Design theory and calculations: The following parts were considered for the design. 1. Geared D.C motor, 2. The Extension Arm   3 . Roller tube and 3.Stand as column

Determination of Torque transmitted by the D.C Motor: A geared D.C motor having a speed of 2500r.p.m powered by 12volts and 5 ampere is used to drive the rain shade system. The power input by the motor is given by; $P_I = IV$ (1)   The angular speed (w) is given by ; $w = \frac{2\pi N}{60}$ (2) The torque developed (T) according to khurmi and Gupta (2005),is given as; $T = \frac{P \times 60}{2\pi N}$ (3)

Design of Worm Gear: The worm gear is used to reduce the speed of the roller tube while increasing the final torque transmitted to the roller tube, using a velocity ratio(V.R) of 10:1. Torque developed by the worm gear, which is the final torque transmitted to the device (T$_f$); $T_f = T \times V.R$ (4)

According to khurmi and Gupta (2005), the number of teeth on the worm gear T$_G$; T$_G$ =$V.R \times T_W$ (5) According to Bhandari(2014),the recommended value of (m) for general purpose worm gear with V.R 10:1 and a 80mm centre distance is 4. From khurmi and Gupta(2005), the pitch circle diameter of the gear , $D_G = m \times T_G$ (6)

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The outside diameter D_{OG} $D_{OG} = D_G + 0.8903P_C$

(7) . Axial pitch p= $\pi \times m$ (8) Throat diameter, $D_T = D_G + 0.572P_C$ (9) Face width,   b= $2.15p_c+$ 5mm (10)

Determination of weight acting on the Extension Arm: The measured weight of the polyester fabric equals 14.7N, while the combined measured weights of the two PVC lead tubes equal 4.9N, the two sleeves have a combined weight of 0.5N. The sum of all these weights gives the total weight acting on the extension arm.

 Weight acting on each extension arm $= \frac{Total\ weight}{2}$ (11)

Determination of Roller Tube Diameter: It is powered by the D.C motor and also has imbedded in it the springs which extends and retracts accordingly. It is 1.2m in length. It is made of timber with shear strength of 2.2Mpa and its factor of safety is 8. (www.woodsolutions.com).
$allowable\ shear\ stress, \tau = \frac{maximum\ shear\ stress}{factor\ of\ safety}$
(12) According to Khurmi and Gupta (2005), twisting moment,T is given as $T = \frac{\pi \times \tau (d_o^3)(1-k)^4}{16}$ (13)
Where d_o and d_i are the outer and inner diameter of the roller tube.

Determination of load carrying capacity of the stand:The material used for the stands is a mild steel 25mm square hollow pipe, having thickness of 1mm, with a crushing stress of 320N/mm^2 and Young Modulus, E of 0.21 $\times 10^6$ N/mm^2. According to Khurmi and Gupta(2005), $crushing\ stress = \frac{c\pi^2 E}{(\frac{l}{k})^2}$
(14)
Where C = Constant of end condition = 0.25, L = Equivalent length of the stand, K = Radius of gyration and $\frac{l}{k}$ =slenderness ratio
The radius of gyration is given by Hall *et al*(2004)as
k= $\frac{h\sqrt{3}}{6}$ (15)   where h= b=25mm = the width of the hollow square pipe. The actual length of the pipe

is 1000mm, so the equivalent length of the pipe is 2000 mm
Euler formula was used to calculate the buckling load of the stand, in line with the conditions given by Khurmi and Gupta(2005). The buckling load $w_{cr} = \frac{c\pi^2 EI}{l^2}$ (16)   The least moment of inertia of section of the column I $=\frac{BD^3}{12} - \frac{bd^3}{12}$ (17) Where D =B= Depth of the outer section=25mm and d = b = 23mm=The depth of the inner section of the hollow square pipe.

Development of the Sensor Unit: The rain sensor was purchased and installed. It has the following technical specifications: Power supply rated voltage is DC 15-30V, current consumption approximately 10Ma. Heating rated voltage is AC/DC24V and maximum power consumption of 4.5W.
  The exploded views and assembly drawing of the rain shade are shown in figures 1 and 2 respectively.

Performance Evaluation: Cobs of maize were spread directly under the device to serve as one of the agricultural produce that is being dried and protected. The sensor's open circuit was sprinkled with water which served as the rain water and the rain shade automatically opened and covered the cobs of maize. It retracted when the water dried up.

RESULTS AND DISCUSSIONS
The final torque transmitted by the geared D.C motor was evaluated to be 2290 Nmm. The gear parameters such as the number of teeth, pitch circle diameter, outside diameter, axial pitch, throat diameter and face width were determined to be 40, 16 mm, 27.19 mm, 12.57 mm, 23.1 9mm and 32.03 mm respectively. The weight acting on each extension arm was found to be 12.5N. The roller tube inner and outer diameter were determined to be 45mm and 50mm respectively. The load acting on the stand was found to be 106.3N. Since it is less than the determined buckling load of 1195.5N, the stand is safe.

The results of the performance evaluation of the rain shade are depicted in Table1

.**Table 1** Sprinkle, Response and Return time of the device with ambient temperature

S/N	Ambient Temperature(^{o}C)	Sprinkle time(s)	Response time(s)	Return time(s)
1	28	1	0.5	1.50
2	30	5	1	41.1
3	30	10	1	470
4	30	20	1	480

From the first reading of the response time in Table 1, it was observed that the device responded to the

water sprinkled and opened in 0.5s. This is due to the fact that enough water was made to touch the sensor

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and bridge the gaps of the circuit. But for other readings, as the sprinkle time increased, the response time was almost constant or within 1 second and the

return time increased. However, the return time increased with varied ambient temperatures as these are evident in Table 1.
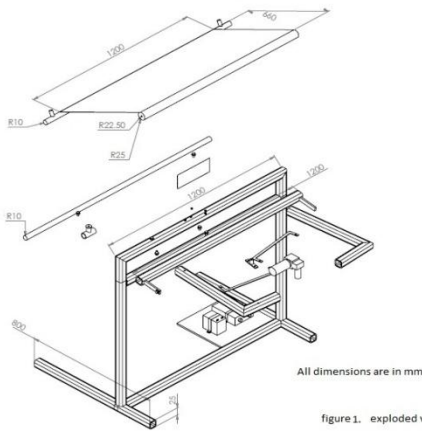

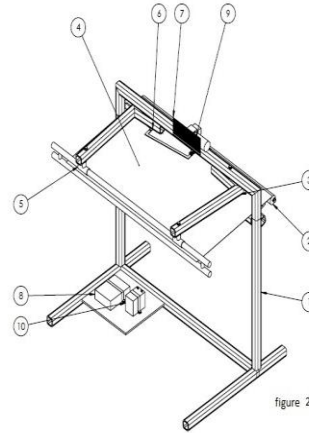figure 1. exploded view of rain shade

All dimensions are in mm

figure 2. Assembly drawing of rain shade

Conclusion: This investigation has shown that the rain shade constructed in this work is economically viable and can be used anywhere because of its compatibility, it requires little investment and is environmentally friendly. It can be used mostly in rural areas of some developing countries like Nigeria where the electricity supply is not reliable. It can be adapted for shading other drying materials from rain.

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