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Research Paper

Auto-Regulating Solar Dryer for Variety Seedlings Production

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Abstract: *Drying is a normal part of the seed maturation process. Some seeds must dry down to minimum moisture content before they can germinate. Low moisture content of seed is a pre-requisite for long-term storage, and is the most important factor affecting longevity. Seeds lose viability and vigor during processing and storage mainly because of high seed moisture content (seed moisture greater than 18%). High germination percentages and rates, with relatively good uniformity, are important factors for successful commercial seedling production. The principal factors influencing seed germination are temperature, water, oxygen and light, of which temperature is the most significant as it affects both the germination percentage and germination rate. In the local setting of subsistence farming; fresh seeds and cobs are kept at the chimney top for some months to dry down and germinate easily during the next season. The warm flue gases from the grate are enough to dry them overtime. Drying in the sun normally serves well for food grains but most times destroy the embryo in the seedlings as a result of excessive temperature. Commercial agriculture require that large quantities of seeds are dried at the requisite temperature before storage to ensure lively embryos which would readily germinate when planted. This work contrives an automatically regulating solar drier for seedlings production to ensure that drying is executed at the requisite temperature that would maintain viability of the seedlings for germination. The equipment can be used for production of various seedlings as provisions are installed for adjusting the temperatures and maintaining constant conditions during the drying process. This is achieved through a secondary heat booster and specific chamber thermostats.*

Keywords: *Agriculture, Seedlings, Drying, Temperature, Auto-regulating, Production.*

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I. Introduction

Food sufficiency has become one of the core concerns of various national policies. These concerns have been founded on the dire need to tackle the problem of production, processing, storage and sustainability of food products that are available to the people for consumption. Grain conditioning by drying and cooling to target ranges should begin immediately after harvest (Sadaka*et al.*, 2017), Therefore, handling and storage of farm produce must be emphasized to reduce postharvest losses. Seed drying is a very important post harvesting technique, which assures seed quality by avoiding microorganism and insect attack on seeds (Carvalho and Nakagawa, 2000).Dying is the process of reducing moisture content of a material to a level that is safe for storage and/or processing. The essence of drying farm produce is to remove excess water from products until it reaches the ideal level of moisture content (Domingos*et al.*, 2012). Drying of agricultural products is the most critical operation after harvesting a crop in which delays in drying, incomplete drying or ineffective drying will reduce grain quality and result in losses. Storing of moist grains without reducing the moisture content will make them breathe more quickly, heat up the grains, and result to rapid deterioration. If grains contain too much moisture in them, heat increases more quickly, fungi develop fast and/or may proceed to germinate

The basic function of a dryer is to supply the product more heat than is available under ambient conditions thereby increasing sufficiently the vapour pressure of the moisture held within the crop and decreasing significantlythe relative humidity of the drying air and thus increasingits moisture carrying capacity and ensuring sufficientlylow equilibrium moisture content(Umogbai*et al.*, 2013).Several different grains drying systems are used across the globe. The type of dryer chosen for a particular operation depends primarily on daily harvest rate and incoming grain moisture content. Meanwhile, recommended operating conditions for each system are based on an efficient combination of airflow and heat to match the desired amount of moisture removal needed for safe storage.The adoption of artificial drying of agricultural products is a technology that usually utilizes a high cost equipment with high energy consumption in order to heat the air used for drying (Reinato*et al.,* 2002; Sharma *et al.,* 2009). Hot air-drying systems are common for drying grain, but natural air-drying systems are lower cost and increase the capacity for managing tough grains.

The supply of solar energy is abundant in most locations in Nigeria where solar heat is intense virtually all the year round. (Irtwange, 1991; Folaranmi, 2008; Yohanna*et al.,* 2011). Nigeria lies within the equator and is blessed with abundant solar energy all the year round (Twidell and Weir, 1986). Solar energy can easily be harnessed by a proper design of solar dryers for crop drying. This method of drying requires the transfer of both heat and water vapour (Ezekoye and Enebe, 2006).Open air sun drying has been used since time in memorial to dry plants, seeds, fruits, meats, fishes, woods and others agricultural or forest products as means of preservation. However, for large scale production, a number of limitations are encountered for open air drying, among these are: large area requirement, possible degradation due to biochemical or microbiological reactions, insect infestation, high labour cost, lack of ability to control the drying process amongst others (Yanoy*et al.,* 2011).

II. Statement of problem

Most grains dryers in Nigeria today offer scarcely controlled heat which may be less or beyond the required energy. They are usually open Sun drying, direct solar drying and electric dryers. Their attendant higher temperatures and mechanical activities which damage the germination percentage and other nutritional qualities of the grains are barriers against sound seedlings production. Maintaining seedling productions quantity is key to enhancing yield and profit in the agricultural sector. This project is contrived to tackle the bottle necks encountered in previous systems and offer, temperature control, time, germ quality management and less seeds handling as well as lower cost heating system for drying varieties of grains.This project envisages major gaps between seedlings productions, availability and quality control. It is aimed to design a sized solar dryer with auto-regulating features to ensure drying of various crops' seeds at specified temperatures for the production of variety crop seedlings for planting.

III. Literature Review

Over the last two decades, open air sun drying has slowly became limited because of the requirement for large area and time covered, the possibilities of quality degradation and process control, high level of dust and atmospheric pollution from the air, cloudiness and rainfall, interruption from animals and man, infestation by birds, insects and rodents, inherent difficulties in controlling the drying process (Iqbal and Ahmad, 2014).It is suggested that when drying grains using a patio with a cement floor in the sun that the grain must be turned over frequently so that it can dry more quickly and evenly. If the grains are to be used as seeds, then it is recommended to turn the grains over always, so that the cement floor temperature does not rise above 40^{o}C.

Domingos*et.,al* (2012) researched on the test procedures using the LINSEC toolset for modelling and simulating a concurrent flow drier and fixed bed dryer, stating that the system has a great advantage of not demanding user knowledge of programming languages. According to the result obtained, final moisture content simulated by LINSEC was higher than results obtained by Queiroz et al. (1988). The mean and maximum absolute differences between simulated and experimental final moisture content were 1.05% w.b. and 1.63% w.b., respectively. Queiroz*et al.*, (1988), in the same comparison, using the MSU model, obtained the mean and maximum differences of 0.35% w.b. and 0.70% w.b., respectively. Also, that the largest error observed in the study could probably have been caused by lower accuracy in the Thompsons's model, with drying temperatures above 100 °C.According to Songül*et al.,* (2013), investigate the drying kinetics and the quality characteristics of corn kernels, especially on effects of different initial moisture contents (18.3%, 26.3%, 34.3% and 42.3% db), micro wave power levels (70, 175 and 245 W) and exposure time of (80 s and 120 s), which reviled that increase in exposure time and initial moisture content decreased the germination rate of corn. And increase of water vapour pressure and temperature inside the grain led to reduction of germination of corn depending on the level of micro wave power used.

Iqbal and Ahmad (2014), researched on a heated-air dryer which was loaded with a quantity of 4 tons of ear-corn and drying time of 9 hours was recorded. A solar passive dryer which in fall 2010 recorded an ambient air temperature of 31^{o}C and 35.2^{o}C average air temperature inside the solar passive dryer, with an average initial and final moisture content of ear corn to be 26.1% and 18.9%, respectively with a decrease of 7.2 percentage point in moisture content of ear-corn within 4 days. Whereas in spring, 2011, average ambient air and inside air temperature solar passive dryer during the tests was 39.1^{o}C and 43.5^{o}C, respectively. The final moisture content of 19.4 % from average initial moisture content was 25.5% during the period were observed, which had 6 percentage points moisture reduction in ear corn grains during the tests for the Heated-air dryer. However, an average drying/ plenum air temperature of 55.8^{o}C was achieved to dry ear-corn and the average exit air temperature of 45.8^{0}C was recorded. It is also stated that drying of ear-corn using solar passive dryer was weather dependent, as it cannot be dried in cloudy conditions, and almost same time required for drying ear-corn in fall and spring season for heated-air dryer, but gas consumption for heating air was more in fall as compared to drying spring crop. Hence, maize grower may select any drying techniques for their crops depending upon weather conditions and speed of work they require.

A Passive solar dryer which was designed and constructed by Umogbai and Iorter, (2013) recorded a minimum and maximum temperatures of 40.0^oC and 59.0^oC respectively at the heat collector, also a minimum and maximum temperatures of 35.0^oC and 48.0^oC respectively in the drying chamber. This enables the initial moisture content of 30.3% of the harvested fresh maize to drop to 13.3% on the third day of drying. They observed that, the maize cobs in the dryer looked cleaner than those which were sun dried and stated that performance of the dryer should be evaluated over a longer period of time of about one month as a result of changes in weather to ascertain its maximum efficiency.

A small-scale maize– on – cob heated-air dryer developed by Adekanye*et al.,* (2016) achieved a drying temperature of about 42°C - 73°C, with a drying capacity of 10kg per drying batch. Corn waste served as a means of heat source which consumed about 1.5kg/hr for 7 hours per day, within 3days to drop the initial moisture content of 76.80% (wet basis) of corn to 13.32% (wet basis) which is the safe storage moisture content for maize. The system requires another external power to supply electricity to the fan to circulate the heated air round the entire drying chamber.The research conducted by Gausman*et al.,* (1951) stated that at a controlled humidity and air velocity, corn varying from 24 to 75% initial moisture content was artificially dried at high (181.2^o F), medium (129° F), and low (109.8^o F) temperatures showing that at temperatures of 180^o and 130^o F, there was a significant differences in niacin, pantothenic acid, riboflavin, pyridoxin, total sugar, and the starch content found when corn of high moisture content was dried. Although, artificially dried immature corn was more brittle than air-dried corn, and corn samples with initial moisture content of 65.4 to 69.0% gave, upon processing, lower recovery of starch and concomitantly higher amounts of starch in fibre and protein fractions than the air-dried controls. Whereas, the amount of protein in the fibre fraction decreased as corn advanced toward maturity, while starch in gluten and fibre fractions increased.

IV. Equipment Description

Figure 1 is the labelled drawing of the novel “Auto-Regulating Solar Dryer” depicting important components which include: a Heat Collector (68), Heat Sink (69) and Solar Panels (95) that generate the electricity required to drive two Blowers (29), a Hot Air Blower and a Cool Air Blower as well as two DC Motors (81) which drives Reflector Levelling Heads (83). Direct Sun rays on the Heat Collector and Heat Sink traps heat energy in the Heat Collector and Heat Sink.

Apart from storing direct energy from the Sun, the Heat Sink is also thermally energized by heat energy extracted from the Sun by the Reflector through the Hot Plate. The Heat Sink releases heat stored up to augment the heat energy in the Heat Collector as needed. The Heat Sensors measure the mixed air temperature that will be used for drying in all the drying chambers. The thermostat is set to regulate the speed of the hot air blower and velocity across the delivery channels. As the temperature of the heatsink rises, so does the hot air blower speed and velocity, and similarly as the heatsinks’ temperature drops, so does the blower speed and hot air velocity. The Auto Regulating System employs a programmable Arduino integrated circuit board which coordinates operations of the heat sensors, digital thermostat, accelerometer and GPS breakout boards to ensure that the Hot Air Blower takes hot air from the Heat Collector into the Drying Chamber at a rate set by the Auto Regulating System to maintain specified drying temperature.The major parts of the solar dryer include: Drying chamber, back up heater and the airflow system.

The dryer is designed with a solar heat enhancement system in order to sustain regular heat supply under a high air velocity over a longer period of time. The system also improves heat generation when low solar heat radiation occurs. A digital thermostat system is built in other to regulate heat supply.

Maximum heat supply to the grains can be regulated as desired, either for seedlings or consumption. Therefore, fans are provided to mobilize heat generated all through the drying chambers. Also, a fresh air vent fan within the system regulate and maintain air temperature without dropping air velocity. Figures 2, 3 and 4 are the orthographic, isometric and exploded drawings of the Auto-Regulating Solar Dryer.

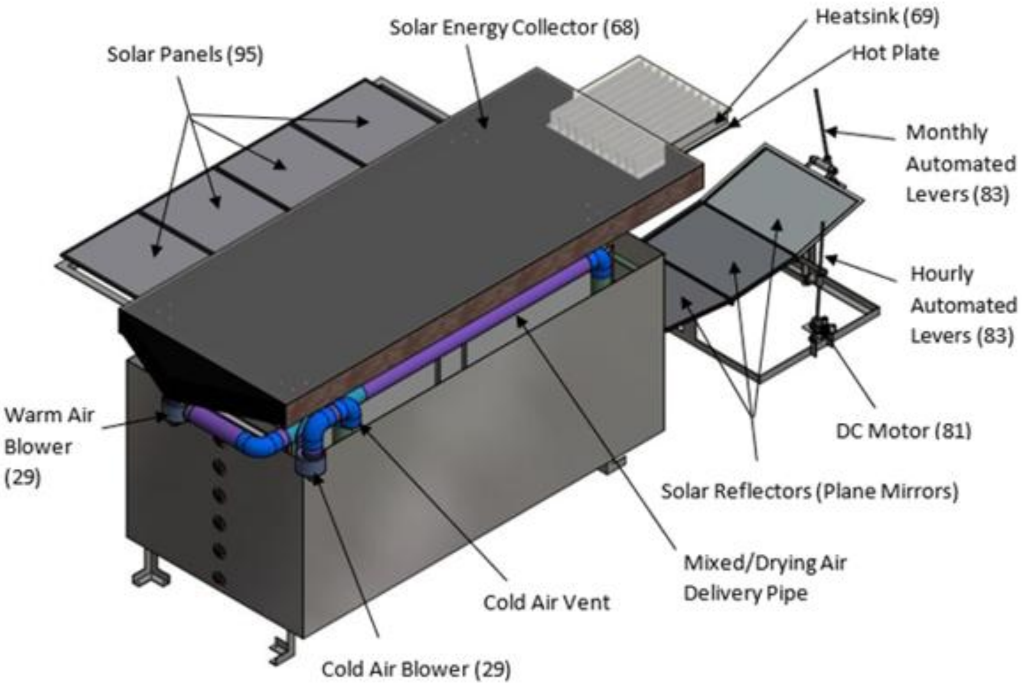


Figure 1: Auto-Regulating solar dryer

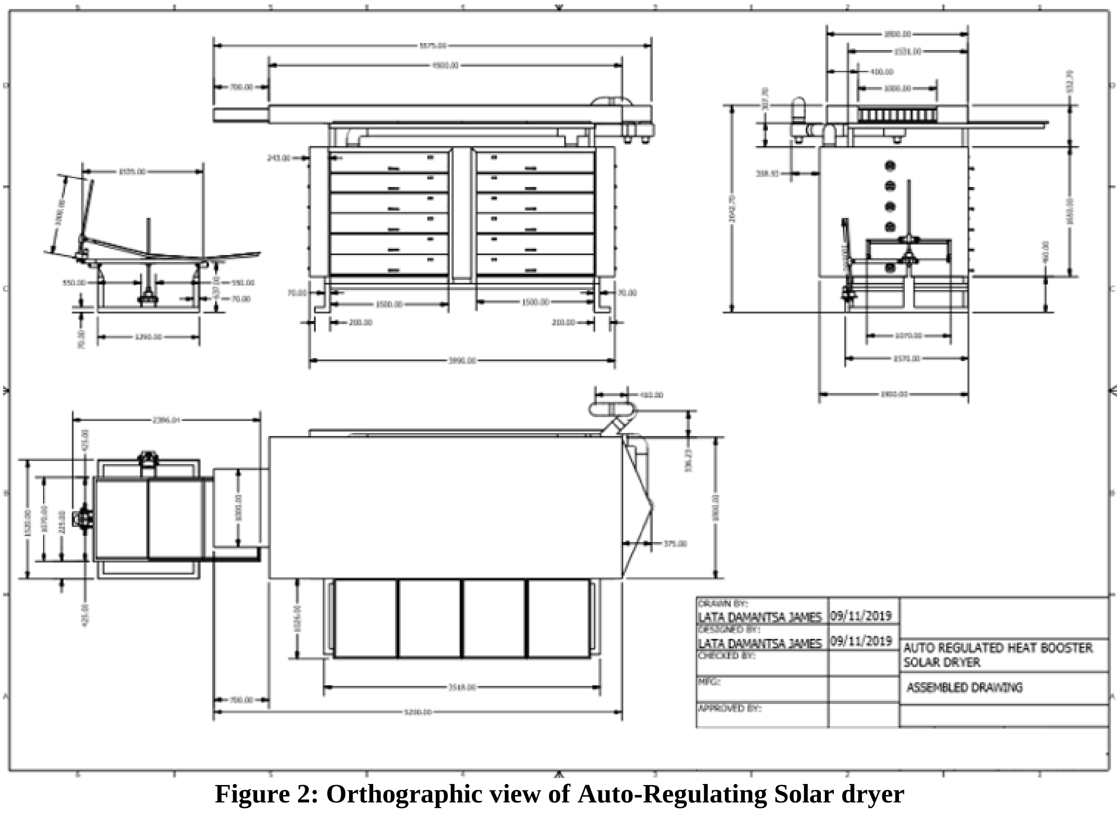
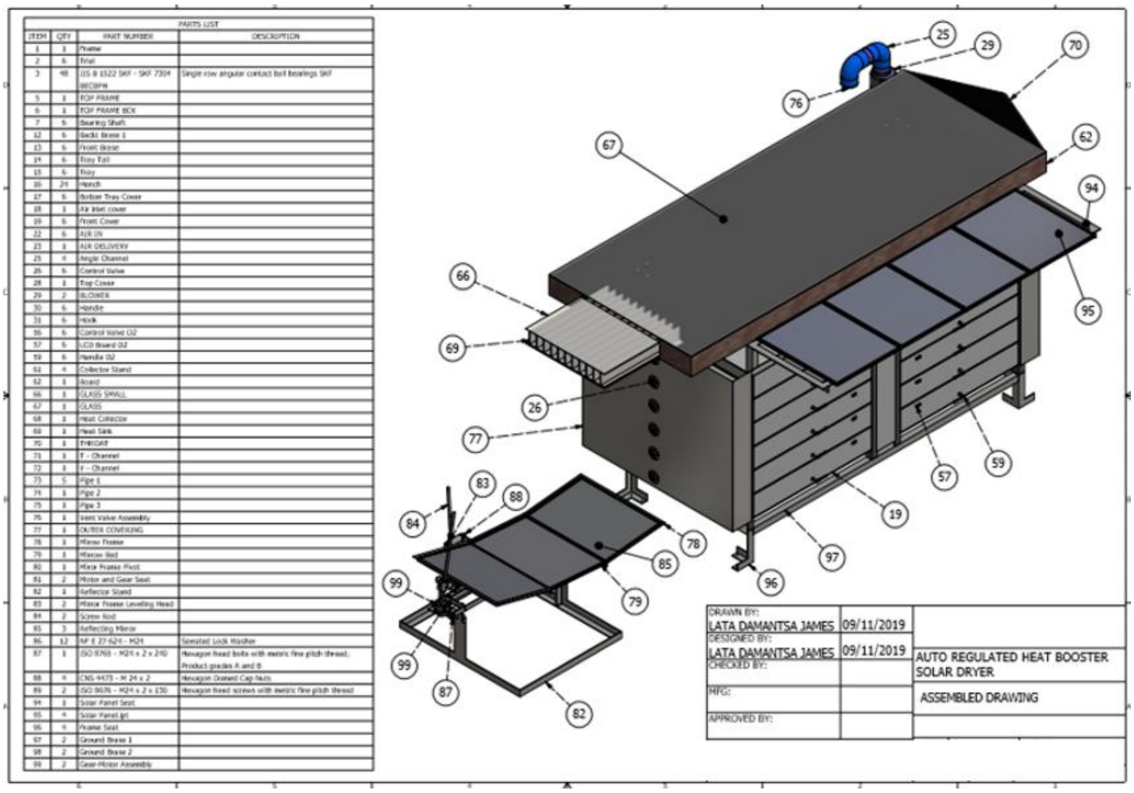


Figure 2: Orthographic view of Auto-Regulating Solar dryer



PARTS LIST

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Frame	
2	6	Trial	
3	48	JIS B 1522 SKF - SKF 7304 BECBPH	Single row angular contact ball bearings SKF
5	1	TOP FRAME	
6	1	TOP FRAME BOX	
7	6	Bearing Shaft	
12	6	Back Brace 1	
13	6	Front Brace	
14	6	Tray Tail	
15	6	Tray	
16	24	Hench	
17	6	Bottom Tray Cover	
18	1	Air inlet cover	
19	6	Front Cover	
22	6	AIR IN	
23	1	AIR DELIVERY	
25	4	Angle Channel	
26	6	Control Valve	
28	1	Top Cover	
29	2	BLOWER	
30	6	Handle	
31	6	Hook	
56	6	Control Valve 02	
57	6	LCD Board 02	
59	6	Handle 02	
61	4	Collector Stand	
62	1	Board	
66	1	GLASS SMALL	
67	1	GLASS	
68	1	Heat Collector	
69	1	Heat Sink	
70	1	THROAT	
71	1	T - Channel	
72	1	Y - Channel	
73	5	Pipe 1	
74	1	Pipe 2	
75	1	Pipe 3	
76	1	Vent Valve Assembly	
77	1	OUTER COVERING	
78	1	Mirror Frame	
79	1	Mirror Bed	
80	1	Mirror Frame Pivot	
81	2	Motor and Gear Seat	
82	1	Reflector Stand	
83	2	Mirror Frame Leveling Head	
84	2	Screw Rod	
85	3	Reflecting Mirror	
86	12	NF E 27-624 - M24	Serrated Lock Washer
87	1	ISO 8765 - M24 x 2 x 240	Hexagon head bolts with metric fine pitch thread; Product grades A and B
88	4	CNS 4473 - M 24 x 2	Hexagon Domed Cap Nuts
89	2	ISO 8676 - M24 x 2 x 150	Hexagon head screws with metric fine pitch thread
94	1	Solar Panel Seat	
95	4	Solar Panel.ipt	
96	4	Frame Seat	
97	2	Ground Base 1	
98	2	Ground Base 2	
99	2	Gear-Motor Assembly	

DRAWN BY: LATA DAMANTSA JAMES	09/11/2019	
DESIGNED BY: LATA DAMANTSA JAMES	09/11/2019	AUTO REGULATED HEAT BOOSTER SOLAR DRYER
CHECKED BY:		
MFG:		ASSEMBLED DRAWING
APPROVED BY:		

Figure 3: isometric view of Auto-Regulating Solar Dryer

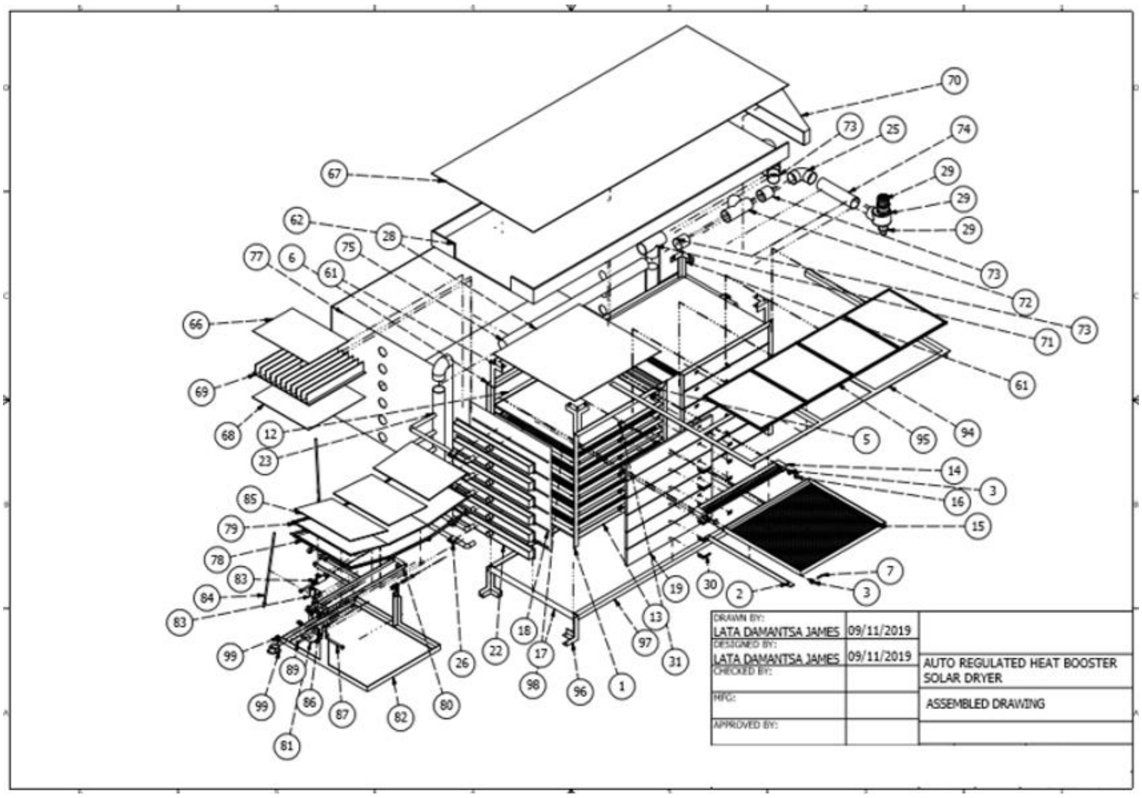


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Figure 4: Exploded view of Auto-Regulating Solar dryer

Some components pertinent for the provision of the auto-regulating features are succinctly explained hereunder:

i. **Electric Power Generation:** Electricity is required to power the monitor circuits, automated levers and blower motors that convey both the heated and cold air when necessary. These consist of solar panels, storage batteries and charge controller.

Charge controller

ii. **Heat Booster:** The maximum heat energy of a terrestrial surface facing the sun on a clear day around noon at sea level is $1000W/m^2$. Meanwhile, drying gets more effective when there is adequate motion of heated air going in and out the drying chambers. Although, most solar dryers are designed to obey thermodynamics without mechanical enhancement. Hence, introducing an enhanced system for faster movement of air in and out the drying chamber will lower the temperature of the air required for an effective drying as it lowers the drying time which canresult in product damage as the case may be.However, reflecting mirrors have efficiency of reflecting about 90-95% of solar energy. Thus, the heat booster consists of reflecting mirror ($2.1m^2$), heatsink (aluminium 1000 X 800 X 100mm), hot plate (mild steel 1000 x 700 x 2mm) and DC motors for solar tracking. The heat collected by the hot plate over time is at its peak as the incident sun rays at the middle of the reflector is maintained around the centre of the hot plate as it reflects (i.e. regardless of the direction of the sun as is rises and falls, the reflector must maintain its reflected rays fully on the hot plate at all angles of incident). Whereas, the area of the reflector ($2.1m^2$) is set to converge solar energy on the hot plate surface area ($0.7m^2$), causing its temperature to rise while its' been transferred to the heatsink.

Digital Thermostat

iii. **Auto Regulating System:** This uses a programmable Arduino integrated circuit board with components connected to it such as heat sensors, digital thermostat, accelerometer and GPS breakout boards.

Arduino Integrated Circuit BoardMixed/Drying Air Temperature Regulator

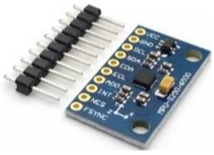
Individual Drying Chamber Thermometer

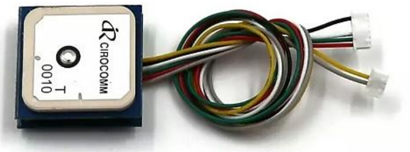
In the regulating system, two heat sensors are used, one at the hot air blower to measure the heated air temperature while the other at some millimetres away from the cold air pipe connected to the delivery channel to measure the mixed air temperature that will be used for drying in all the drying chambers. Moreover, a thermostat is connected on the heatsink that will control the speed of the hot air blower. This will help to control and maintain the drying air temperature and total utilization of the heat generated by the heat booster for effective drying at a regulated temperature and higher air velocity without causing damage to the seedlings and/or produce to be dried. The thermostat is set to increase the speed of the hot air blower and hot air velocity across the delivery channels. As the temperature of the heatsink rises, so does the blower speed and hot air velocity, while the heatsinks' temperature drops, so does the blower speed and hot air velocity.

Heat Sensor

The mixed and hot air sensors are connected to the Arduino circuit, sending their current temperature status for computation. Using a C++ programming language, the circuit computes the appropriate temperate of the mixed air whereas deciding on increasing the volume of the cold air by increasing the speed of the vent blower to the stream or reducing to the volume of cold air and speed of blower as well as to equal the mixing proportion ratio for a desired mixed temperature. Although, mixed air temperature is manually configured on the temperature adjustment buttons which gives room for multi-purpose drying. Therefore, the heat going into the drying chambers cannot exceed the maximum temperature set on the display unit board.

Furthermore, two (2) accelerometers and a GPS breakout boards are also connected to the Arduino circuit board. The GPS device receives a raw NMEA data from the satellite, which will be converted to real data that consists of time, date, coordinates, compass and altitude amongst others of its current location. These date and time will be used for tracking the suns' angle of incident rays according to the month and time of the day. From sun rise to sun set, the rays will be tracked and followed by the use of the accelerometers, sending data of the reflectors' inclinations. Whereas, the Arduino circuit computing the codes received from the GPS device and accelerometers to adequately and promptly adjust reflectors' angles till it matches the simulated angles programmed for each of the accelerometers according to the hour of the day and month of the year, by rising and lowering of the adjustment levers using a DC motor.





Accelerometers Breakout Board   GPS Breakout Board

V. Conclusion

Seedlings of various crops are scarce each farming season and impact negatively on agricultural production in Nigeria. Post-harvest uncontrolled sun drying in the open and uncontrolled solar drying render excessive heat to the seeds thereby killing the embryo and making the seeds good for consumption only. Over the fire grate practised by peasant farmers do not provide enough seeds for cultivation. The lack of technologies for commercial seedlings production is a setback to crop production in Nigeria. This work contrivesa requisite technology to curb excessive drying and the consequent destruction of seed embryos leading to production of active fertile seedlings in commercial quantities. It is hoped to boost availability of seedlings in Nigeria.The incorporation of a heat sink and reflective plates ensures longer heat availability. Electrical control components namely thermostats, charge controllers, breakout boards, heat sensor are all coordinated to effectively deliver required heat at the specified temperatures once there is sunshine.

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